

N71-32567

NASA SP-5935(01)

TECHNOLOGY UTILIZATION

COMMUNICATIONS AND TELEMETRY

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A COMPILATION



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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## Foreword

The National Aeronautics and Space Administration has established a Technology Utilization Program for the dissemination of information on technical developments which have potential utility outside the aerospace community. By encouraging multiple application of the results of its research and development, NASA earns for the public an increased return on the investment in aerospace research and development programs.

This publication is part of a series intended to provide technical information concerning communications and telemetry. The concepts, methods, and innovations are divided into five sections. The first section concerns antennas and antenna systems, some of which involve complex satellite performance, while others have application for land transmitting and receiving stations, ships, and radio and TV stations. The second group spans biomedicine, featuring implantable monitoring devices. Next, testing and measuring procedures are described, followed by advanced systems technology, including lasers and complex operational centers. The last group involves more specific electronic parts and concepts, especially those pertaining to automated data processing systems. Overall, these items have potential for use with many newly developed methods for the transfer of various data.

Additional technical information on individual devices and techniques can be requested by circling the appropriate number on the Reader's Service Card included in this compilation.

Unless otherwise stated, NASA contemplates no patent action on the technology described.

We appreciate comments by readers and welcome hearing about the relevance and utility of the information in this compilation.

Ronald J. Philips, Director  
*Technology Utilization Office*  
*National Aeronautics and Space Administration*

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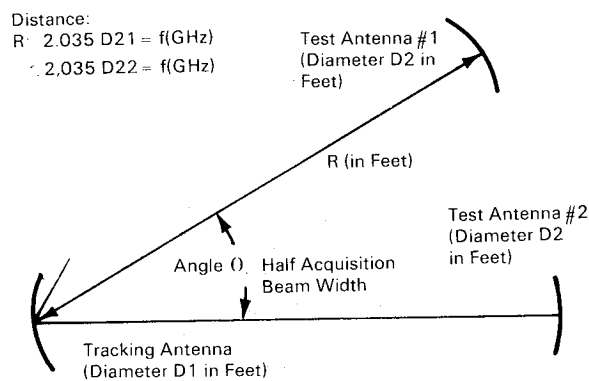
## Section 1. Antennas and Antenna Systems

### IMPROVED CONCEPTUAL TEST METHOD FOR ANTENNA TRACKING SYSTEM PERFORMANCE

A tracking antenna is used in a system where two objects are changing position with respect to each other. The test antenna is moved in the X-Y plane corresponding to the movement around the X-axis of the tracking antenna which is pointed away from a fixed test antenna and then allowed to zero-in on it. However, a more elaborate test method is required when reacquisition, station hand-over performance, and other parameters must be checked out.

The improved test method uses more than one test antenna in a fixed position, forming an array which creates numerous radiation patterns for testing. No moving test antennas are required to simulate the relative motion between test and tracking antennas. This approach should have numerous industrial communications applications and should be adaptable for use in the TV industry.

As shown in the figure, the angle  $\theta$  between the test antennas and the tracking antenna should not exceed half the acquisition beamwidth of the tracking antenna. The test distance  $R$  should be the far-field distance of the antenna under test to prevent false lock-ons caused by the side-lobes. The test signal should resemble the signal to be



Some Parameters Determining Location of Antennas

used eventually in the system. When a tracking antenna is to be used in a two-way communication system employing phase-lock loop receivers, provisions should be made to duplicate this mode of operation in the test setup.

Source: Pieter J. Berndsen of  
North American Rockwell Corp.  
under contract to  
Manned Spacecraft Center  
(MSC-11626)

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### SCANNING MEANS FOR CASSEGRAINIAN ANTENNA

In microwave antennas, synchronous switching techniques are generally used to detect weak signals over atmospheric and equipment noise sources. These electrical switching techniques involve relatively high insertion losses and equipment complexity that contributes appreciably to maintenance problems.

A mechanical antenna beam switching device has been developed that periodically nutates the

paraboloidal subdish in a cassegrainian reflector system. The antenna beam is switched from the source of interest to an adjacent point in the sky by nutating the hyperboloidal secondary reflector.

The beam switching requires that the secondary reflector rotate  $0^\circ 58'$  about an axis at right angles to its axis of symmetry to produce one direction of the antenna beam. The reflector is then moved past center position  $0^\circ 58'$  in the opposite direction

for the second position of the beam. These positions are periodically repeated at rates of 5 to 15 Hz.

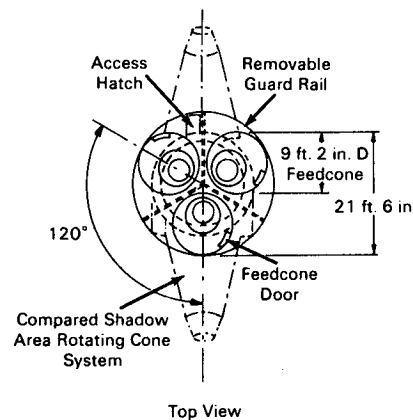
The reflector is moved by a remotely located motor that drives camways through a driveshaft and universal joint arrangement. A cam follower on the reflector traces the cam configuration that imparts the nutating motion. A counterweight,

driven in opposition to the reflector by a cam follower in a camway, cancels momentum of the reflector to minimize vibration.

Source: W. V. T. Rusch and A. Giandomenico  
NASA Pasadena Office  
(NPO-10946)

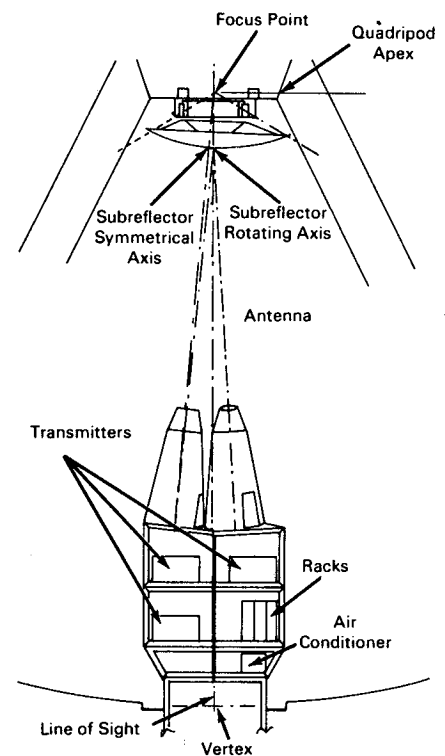
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### MULTIFEED CONE FOR CASSEGRAINIAN ANTENNA



A multiple-cone feed horn system for a cassegrainian antenna using a rotatable hyperboloid in conjunction with a multiple cone system has been developed. The present method to change feed systems on an advanced antenna system is to remove the entire cassegrainian feedcone housing and replace it with another unit. Investigations of various procedures for rapid feedcone changing resulted in a combination which moves hyperboloid relative to fixed multiple feeds and paraboloid, and should interest communications research personnel and manufacturers of communication satellites.

The hyperboloid can be adjusted to be in the best possible position for each feed. Focusing on individual cones is accomplished by rotating the hyperboloid. Advantages of this innovation include: 1) the use of special purpose cones provides improved performance and permits rapid changing of the antenna system from one configuration or frequency to another; 2) spillover is kept to a minimum by use of a configuration having the hyperboloid axis between the para-



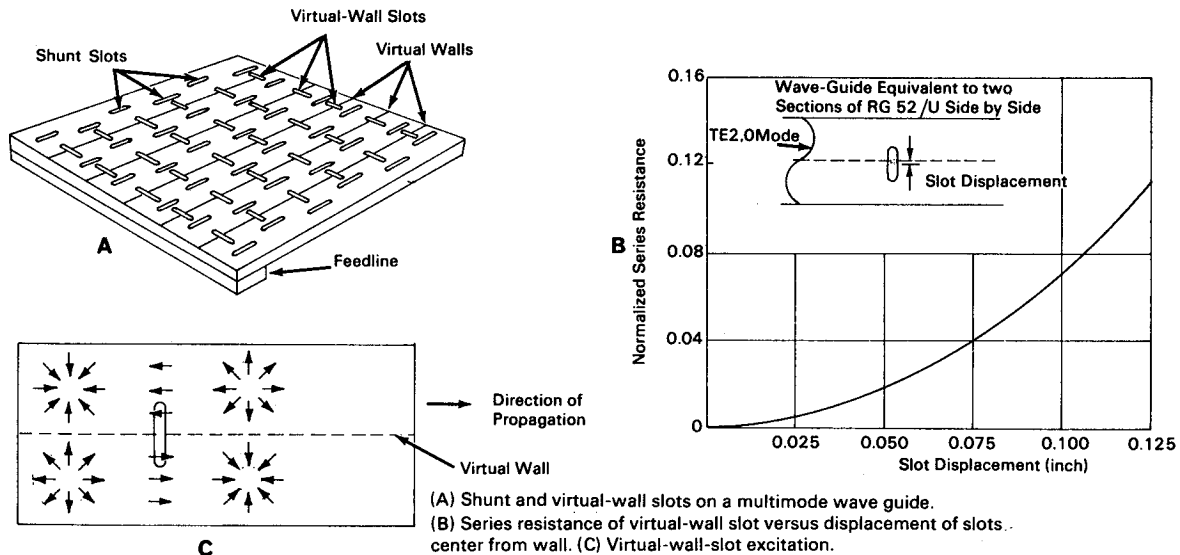
boloid axis and the feed-to-focus line, using an asymmetrical hyperboloid; 3) there is substantially no phase error or boresight shift; 4) simultaneous operation of two cones at different frequencies, using dichroic optics; and 5) return to symmetrical feed is possible for special projects.

Source: Charles T. Stelzried of  
Caltech/JPL  
under contract to  
NASA Pasadena Office  
(NPO-10539)

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## IMPROVED CIRCULARLY POLARIZED PLANAR-ARRAY ANTENNA



This item is primarily a communications antenna that could be used for earthbound links requiring compact planar array antennas having narrow bandwidths; it generates circular polarization in a configuration that is simple, can be built very light in weight, and should be highly efficient.

Formerly, the best-known method of generating a circularly polarized beam, from the aperture of an antenna of the planar-array type, has been to use a high-gain antenna having a planar configuration and generating a circularly polarized beam by means of a combination of crossed slots and pairs of complex slots. To avoid the generation of large end-fire beams and for high efficiency of the aperture, a slow-wave structure had to be used on the bottom wall of the wave guide. The structure took the shape of a corrugated surface.

This new method used slots sitting astride the virtual wall in a multimode wave guide, as shown in Figure A. They do not radiate when perfectly centered on the virtual wall, and the amplitude of excitation is conveniently controlled by the distance of displacement of the slots from the wall, seen in Figure B. Furthermore, in phase excitation of successive slots, with  $\lambda_g/2$  inter-element spacing, Figure C may be effected by alternation of the direction in which the slots are displaced from the wall. The virtual-wall slots can be used for generation of one component of a

circularly polarized beam, with a high degree of efficiency, without use of a slow-wave structure. Shunt slots in an ordinary configuration are used for generation of the other component.

Absence of a slow-wave structure makes the antenna simpler and cheaper to design and build than the earlier type. Another advantage is that the slots are resonant and can be designed as low-Q elements for broadband operation; earlier planar arrays used nonresonant slots that were quite sensitive to frequency.

This slot configuration is now called Slot Configuration No. 1; three more configurations have since been discovered. A "choked" virtual-wall slot now enables design of circularly polarized planar arrays having tapered amplitude distributions in both planes; a nearly solid wall is used along the virtual-wall line, with chokes below the virtual-wall slots. Thus unequal amounts of power may be carried in adjacent waveguides—a condition that was impossible in the older multimode line.

Source: A. F. Seaton of  
 Hughes Aircraft Company  
 under contract to  
 NASA Pasadena Office  
 (NPO-10301)

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### MEASUREMENT TECHNIQUE FOR THE DETERMINATION OF ANTENNA DIRECTIVITY

The directivity of an antenna—the ratio of radiation intensity in a given direction to average radiation intensity—is conventionally measured by integrating conical antenna patterns. In order to generate conical patterns, rotation in elevation with discrete rotation in azimuth is required. The instrumentation required to produce these conditions is necessarily composed of complex slip-rings and rotary joints; use of large, heavier models is also limited. A novel technique eliminates a set of slip-rings and rotary joints, and permits the use of larger models since only continuous azimuth rotation is required. The measurement of great circle patterns requires rotation in azimuth with discrete rotation in elevation.

A spherical coordinate system describes the rotation of the model antenna. Measurements establish the angles for maximum radiation intensity and permit plotting the radiation as a func-

tion of  $\phi$  angles at discrete  $\Theta$  angles. Average radiation intensity is found by double integration of the radiation intensity function over the entire sphere. While this method is convenient, a special technique is required to integrate measurements while they are being plotted. The radiation function is electronically multiplied by the sine of  $\phi$  by coupling the detected signal into a sine potentiometer which is mechanically linked to a polar recorder turntable; the product is fed to an electronic integrator. The integration process is simplified by multiplying the radiation function by the sine of  $\phi$  rather than the first integral by the sine of  $\Theta$ .

Source: L. Rainwater and R. Lipin of  
Sperry Rand Corporation  
under contract to  
Marshall Space Flight Center  
(MFS-12799)

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### A THIRTY-SIX ELEMENT ARRAY ANTENNA SYSTEM

An antenna system has been designed which does not require the movement of the antenna or the presence of an operator. A 36-element square array is used, with mutual coupling between crossed slots for array elements as an electronically scanned tracking antenna. A mathematical model was built using actual values to determine operating characteristics of array elements in different beam scanning directions. This computer design technique produced information pertaining to the number and configuration of antenna elements required for optimum scanning performance in multi-element antenna arrays. Re-

search indicated that the crossed slot arrangement produced a nearly hemispherical pattern, and the resultant beam may be scanned through the entire hemisphere by means of 35 digital phase shifters, capable of shifting phase in 22.5° increments from 0° to 360°.

Source: E. R. Graf of  
Auburn University  
under contract to  
Marshall Space Flight Center  
(MFS-20435)

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### SHORTENED HORN-REFLECTOR ANTENNA

A shortened horn-reflector antenna was designed to overcome the mechanical disadvantages and complexity of the conventional horn-reflector antenna.

The shortened horn-reflector antenna is a modification of the conventional horn-reflector an-

tenna in which the horn is replaced by a hyperboloidal subreflector, and cassegrainian feeding is used. The shortened antenna offers broadband performance, economic construction, very low antenna temperature, and excellent pattern performance. A comparison of the performance of a

model having a 6-foot aperture with that of a conventional horn-reflector antenna is given below. It is assumed that both antennas are operated with a receiver having a temperature of 25° K, at C-band frequencies, and with feed line losses of 0.20 dB.

	Shortened Antenna	Conventional Antenna
Aperture Efficiency	65%	55%
Antenna Temperature	6° K	40° K
Figure of Merit	1.7 dB	-1.46 dB

Source: P. A. Lantz  
Goddard Space Flight Center  
(GSC-90502)

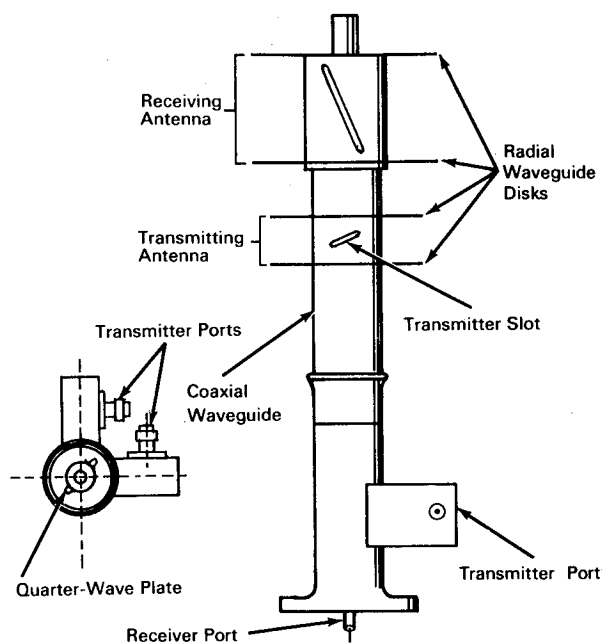
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### OMNIDIRECTIONAL ANTENNAS TRANSMIT AND RECEIVE OVER LARGE BANDWIDTH

This antenna system is capable of exchanging wideband signals between two distant ground stations using satellite airborne equipment as the interconnecting link or relay. The system is comprised of low-gain antennas having wide angular coverage with circular polarization which are mounted adjacently on a single mast extending from the satellite. Two decoupled ports or inputs on the transmitting antenna eliminate switching problems when using two transmitters on different frequencies.

The transmitting antenna consists of two major components: the mode transducer and the radiator. The mode transducer consists of two decoupled input ports at the base of the antenna and a quarter-wave plate between the two ports and the transmitting antenna. Each input port has a short section of rectangular waveguide coupling to the coaxial waveguide through a narrow longitudinal slot cut in the outer conductor of the coaxial waveguide. The coaxial line from a transmitter excites a short probe through the broad face of the rectangular waveguide section. For proper operation, the two ports are oriented at right angles so that the modes excited in the coaxial waveguide will be orthogonal. In addition, the ports are offset longitudinally one guide-wavelength to reduce the direct cross-coupling between ports.

The quarter-wave plate has two longitudinal metal ridges attached on opposite sides of the coaxial waveguide inner conductor. The plane of the ridges lies at 45° with respect to the orthogonal input ports. The dimensions of the ridges are adjusted to convert a linearly polarized wave from either of the input ports to a circularly



polarized wave traveling toward the radiating section. Ends of the ridges are tapered to prevent reflections.

The radiator consists of eight equally spaced slots cut in the outer conductor of the coaxial waveguide above the quarter-wave plate, and a radial waveguide made of two parallel metal disks. The slots are approximately one-half wave in length and are inclined at an angle with respect to the waveguide axis to provide both axial and tangential radiation components. The spacing and diameter of the two disks are adjusted to produce left-hand circularly polarized radiation for excitation of either input port.

The receiving antenna consists of four inclined slots cut in a metal tube and enclosed between two radial disks. This antenna feeds a TEM mode coaxial line extending through the inner conductor of the coaxial waveguide for the transmitting antenna. Right-hand circular polarization is produced by proper adjustment of the disk geometry. The probe length and location, the positioning of the shorting plate in the rectangular waveguide, slot dimensions, and positioning of the slot from

the shorting disk in the coaxial waveguide may be adjusted to provide an impedance match through the transitions of the waveguide.

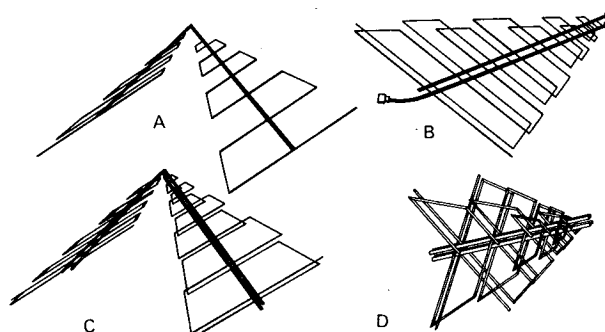
Source: O. M. Woodward, Jr. of  
Radio Corp. of America  
under contract to  
Goddard Space Flight Center  
(GSC-00436)

*No further documentation is available.*

### ANTENNA CONFIGURATIONS PROVIDE POLARIZATION DIVERSITY

The basic trapezoidal tooth log-periodic (TTLP) antenna operates in only one plane and one polarization. Arranging more elements in various configurations to provide dual-plane and multipolarization operation is impractical because of the size of the resulting structure and the interaction that would occur between the various elements.

The angle between the two elements of a basic TTLP can be reduced to zero to form a compact back-to-back antenna with frequency-independent characteristics. The back-to-back antenna, arranged in various configurations, provides monopulse operation in one or two planes and in various polarizations. A single coaxial cable, shielded by the support boom of one of the elements, is used to feed both elements of the back-to-back TTLP (see B in fig.). Arranging two of the back-to-back TTLP's and feeding each independently result in an array of back-to-back TTLP's (see C). Exciting the elements in and out of phase results in frequency independent monopulse operation in one plane and one polarization. Excitation is through hybrids and associated microwave equipment. Extending the structure still further by adding two more elements to form a pyramid would result in monopulse operation in two planes. Dual polarization operation is accom-



plished by employing two of the back-to-back TTLP's and meshing them orthogonally along the same axis (see D). The elements may be fed independently or together, and, by varying the phase or the current, circular and rotating linear polarizations can be obtained. Use of four of the elements (see D) arranged in a four-sided pyramid, permits monopulse operation in two orthogonal linear polarizations and right or left circular polarization.

Source: C. W. Schumacher of  
Airborne Instruments Laboratory,  
Division of Cutler Hammer  
under contract to  
Goddard Space Flight Center  
(GSC-00074)

*No further documentation is available.*

### TECHNIQUE FOR TUNING ANTENNA SYSTEMS PRODUCING NEGLECTIBLE SIGNAL RADIATION

With the use of sweep and marker generators, an antenna system in its operational environment can be tuned and matched to a transmission line

and terminal equipment with negligible signal radiation. The system operates by using an RF sweep generator, connected in a back-to-back

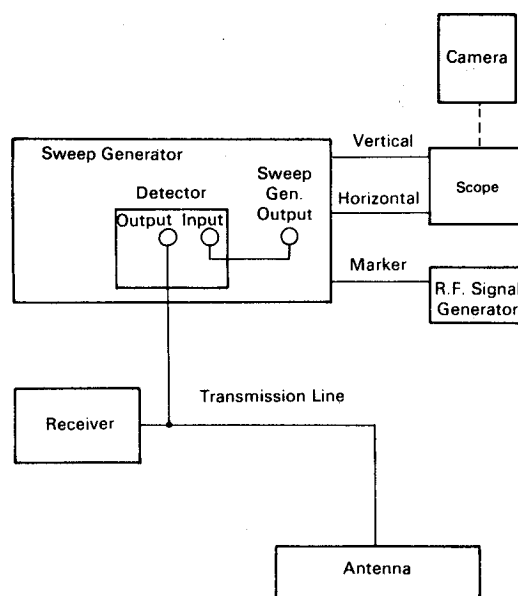
configuration (sweep generator output connected to sweep generator detector input) to simulate transmissions over the entire frequency range of the antenna receiving system. The detector output of the sweep generator is connected to the antenna receiving system near the receiver input.

A sweep generator is a signal generator which has the capability of frequency-modulating the signal generated within the unit. Consequently, the frequency of the signal produced is swept above and below the frequency established by the oscillator within the unit.

The induced voltage standing waves of all frequencies sent down the transmission line and reflected back and forth between receiver and antenna are observed on the oscilloscope. The horizontal sweep of the oscilloscope is synchronized with the sweep generator so that the beam is swept across the face of the CRT as the generator sweeps from the lowest to highest frequency. The oscilloscope traces out the induced voltage standing wave pattern characteristics for all frequencies of the antenna receiving system.

A marker generator (single-signal CW type) is used to identify frequency points along the waveform displayed on the oscilloscope.

Injecting this single signal causes a pip to appear on the oscilloscope. By varying the output frequency of the calibrated marker, the relative positions of the pip will indicate the frequency on the waveform.



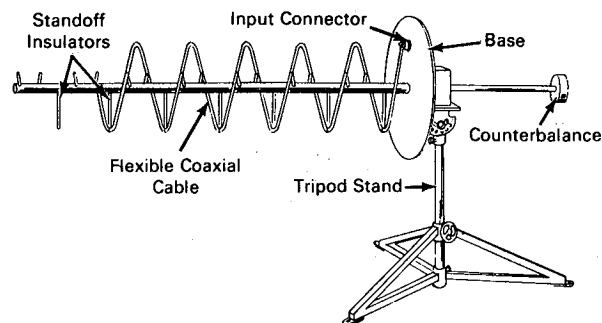
The antenna tuning device is adjusted for minimum standing waves at the precise operating frequency determined by the marker pip on the displayed waveform.

Source: Karl Merz of  
The Boeing Company  
under contract to  
Kennedy Space Center  
(KSC-10060)

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### ECONOMICAL WEATHERPROOF HELICAL ANTENNA

An inexpensive, weatherproof, helical antenna has been built which requires minimum maintenance, and can be transported and assembled



easily. Previously, helical antenna elements have been formed from soft copper tubing, shaped with a custom-machined mandrel. Antennas made by this technique are very expensive, and furthermore, are susceptible to corrosion. These problems have been solved by using a semirigid coaxial cable to form the helical element.

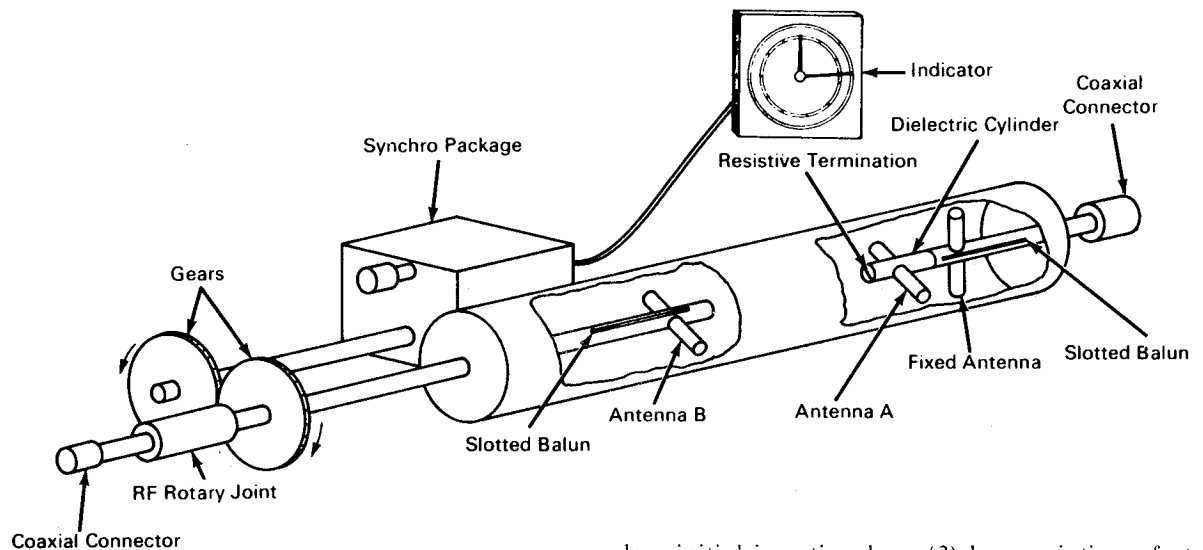
The helix of the weatherproof antenna in the illustration is made of a foam dielectric, helix transmission line that has been shorted out at each end. The helix is formed by mounting the transmission line on standoff insulators, which are attached to the antenna shaft. By this technique, the helix can be formed with any diameter,

pitch, or taper without requiring expensive tools or techniques. Because the p conductors are sealed in plastic, the resulting antenna element is highly corrosion resistant, and may be used at seacoast facilities or on range tracking ships with minimum maintenance.

Source: Herbert E. Cribb  
Kennedy Space Center  
(XKS-08485)

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### ROTARY ANTENNA ATTENUATOR



This accurate radio frequency attenuator, having negligible insertion loss at minimum attenuation, can be used for making precise antenna gain measurements. The apparatus consists of an input dipole antenna electrically coupled to an output dipole antenna within a circular waveguide. The antennas are rotatable with respect to each other. The attenuation is proportional to the angle of rotation  $20 \log_{10} \sec \theta$ ; thus the electrical drive/readout can be calibrated in dB attenuation. The advantages of this configuration are: (1) negligible insertion loss at minimum attenuation compared to a conventional piston waveguide-beyond-cutoff attenuator (which has 20 dB minimum); and (2) small size compared to a rotary-vane attenuator.

The innovation is currently in use as a transfer standard in making precise antenna gain measurements. An S-band version (2297 MHz) has a circular waveguide 4 in. in diameter  $\times$  20 in. long.

The advantages of the innovation are: (1) greatly reduced size relative to competitive devices; (2)

low initial insertion loss; (3) low variation of attenuation with angle:  $20 \log_{10} \sec \theta$  vs  $20 \log_{10} \sec^2 \theta$  variation for rotary-vane attenuators; (4) input and output dipole antennas mounted coaxially in a circular waveguide section and rotatable relative to each other; and (5) calibrated drive/readouts measuring the angle between the planes of the two dipoles accurately, whereby the attenuation may be read directly.

In the figure, an RF signal injected in the RF rotary joint, which allows the angular rotation of antenna B, will be attenuated by polarization mismatch upon excitation through the fixed antenna. This attenuation varies with the angular difference between the planes of the two antennas in accordance with the relation  $20 \log_{10} \sec \theta$ .

The gears, synchro package, and indicator allow the precise reading of angle  $\theta$ . Antenna A, which is oriented  $90^\circ$  with respect to the fixed antenna and coaxial therewith, is provided with a resistive termination in order to match out the cross polarized component between the antennas as antenna

B is rotated relative to the fixed antenna. All antennas are housed in the circular waveguide and terminate in the coaxial connectors.

The excited dipoles are fed by use of slotted baluns. The terminated dipole is supported by a dielectric cylinder that does not require a balun.

Source: R. M. Dickinson and J. C. Hardy of Caltech/JPL under contract to NASA Pasadena Office (NPO-10648)

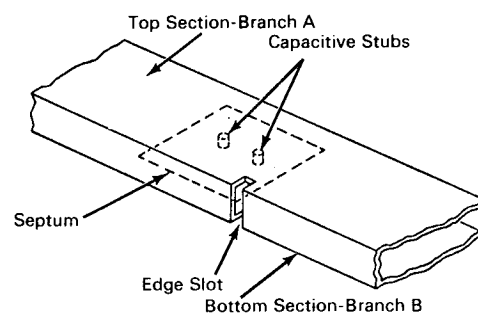
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### PHASE-MULTIPLYING ELECTRONIC SCANNING ARRAY

A scanning array has been designed with properties of low RF loss and phase control. The array consists of a series of special waveguides, hybrids made up of two variable reactance branch arms for input signals, an edge slot for the difference port, and a sum arm for the unradiated signal. The phase of the output signal at the slot is controlled by varying the reactance of the two input branch arms.

The proposed configuration, shown in the figure, consists of an edge slot with no tilt angle, a septum that separates the waveguide in front of the slot, and two capacitive stubs located in the septum. The stubs are free to move back and forth from one branch of the waveguide to the other; a matched impedance is presented at the leading edge and no differential phase shift occurs in the branches when the stubs are centered.

A differential phase shift is generated when both stubs are moved toward Branch A; if one is displaced into each branch line, the power division becomes unbalanced. The two branch lines created by the septum, the edge slot, and the output arm



of the waveguide constitute a degenerate form of a folded E-plane hybrid-tee. The hybrid is normally balanced so that no radiation takes place. This design feature permits relatively small reactance changes to unbalance the power division and generate the phase controlled radiation.

Source: Arthur F. Seaton of Hughes Aircraft Company under contract to NASA Pasadena Office (NPO-10302)

*Circle 10 on Reader's Service Card.*

### RESONANT MICROWAVE DICHROIC SURFACE

A resonant microwave dichroic surface has been developed which has high stopband filter characteristics with a low stopband-to-passband frequency ratio. It utilizes two stagger-tuned, resonant artificial dielectric surfaces and is virtually polarization insensitive. The dichroic surface was developed for use as a hyperboloidal subreflector in cassegrainian antenna systems, but can be used in unique systems which require selectivity in frequency, polarization, or angle of incidence; it can also be used to reduce the radar cross section of an object.

The artificial dielectric surface is constructed from selected metallic elements attached to a thin sheet of natural dielectric and arranged to form a planar array of conductive obstructions. This surface can be made to reflect any one frequency while passing all frequencies above and below the reflected one (provided that the proper choice of metallic element size, shape and spacing has been made). The reflected bandwidth may be increased by stagger-tuning the surface, and further increased by adding another surface in proximity to and parallel to the first.

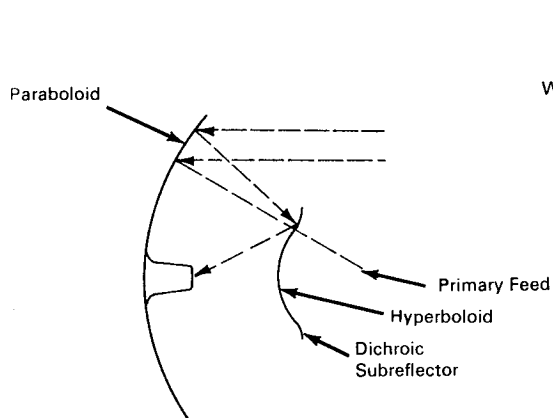


Figure 1. Application in a Cassegrain System

The improvements and advantages over prior methods are: steep transmit-reflect characteristic; low transmission and reflection loss over more than 90% of the usable frequency band; and capability of being designed to have phase correction on the energy transmitted through it by the primary feed (higher illumination efficiency).

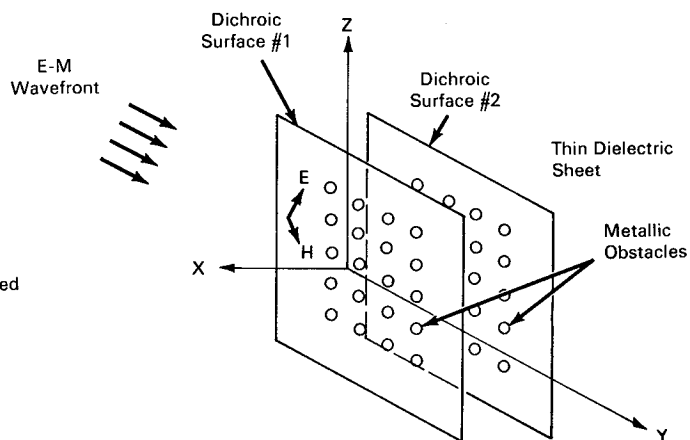


Figure 2. Resonant Two-Section Dichroic Surface

Source: E. G. Sakellaropoulos and H. Estep of Lockheed Electronics Company under contract to Goddard Space Flight Center (GSC-10658)

*No further documentation is available.*

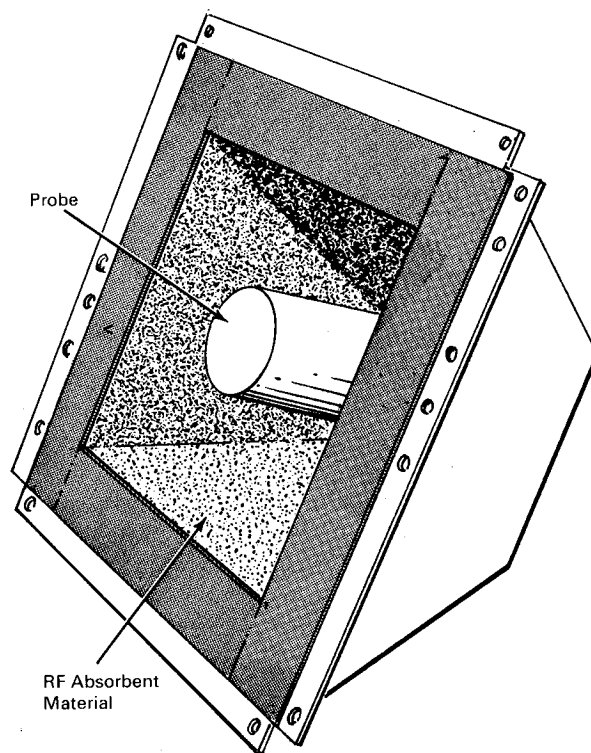
### LOW-LOSS "C" BAND PARASITIC PROBE

A low insertion-loss "C" band parasitic probe has been designed for coupling RF energy from a transmitting medium to a receiving medium with a minimum of interference in order to minimize power requirements. The housing of suitable configuration is made of an RF-absorbent material and within it are mounted a polystyrene rod and helix antenna that form the operating low-loss "C" band parasitic probe. The polystyrene rod acts as a dielectric low-loss path for RF energy. An insertion loss of 10 dB is realized by cementing this rod to the face of a receiving medium helix antenna installed in a housing lined with RF-absorbent material.

This probe requires 20 dB less signal than conventional devices, thus increasing overall system efficiency to a similar degree.

Source: Herbert Edmond Cribb  
Kennedy Space Center  
(XKS-09348)

*Circle 11 on Reader's Service Card.*





### NEW REFLECTOR-TYPE ANTENNA

The best-known reflector antenna is the parabolic type; proper focus requires a point-source feed for illumination of the reflector, severely limiting the control of the amplitude of the illumination function.

This new reflector-type antenna offers almost complete control of its aperture-illumination function, which is its principal advantage. This control enables the engineer to design for either maximum gain or low side lobes, whichever is required. The feed is either a close approximation to a line source, or some structure that is electrically equivalent to one; thus any desired distribution can be designed into the feed. This distribution is then reflected to the aperture of the cone by the conical surface, altered only predictably by the distance traveled by the wave before it strikes the reflecting surface.

Another advantage is that this antenna's beam width can be changed easily by excitation of various amounts of the line-source feed: wide beams

are generated when only a little of the feed, near the apex of the cone, is excited; the beams are progressively narrowed as additional sections of the feed, progressively further from the apex, are excited; and the beam is narrowest when the whole feed is excited. The conical reflector collimates a beam when the feed complies with certain geometric constraints. The line-source feed may be either directly broadside or scanned off at an angle; in either case, a large cross-polarized component exists if the feed is not specifically designed for its suppression. Tests of a prototype antenna have verified the basic concepts of collimation by the conical reflector, and of cancellation of the cross-polarization by specific design of the feed.

Source: A. F. Seaton of  
Hughes Aircraft Company  
under contract to  
NASA Pasadena Office  
(NPO-10303)

*Circle 12 on Reader's Service Card.*

### HIGH-POWER MICROWAVE POWER DIVIDER CONCEPT

Operation of a microwave transmitter occasionally requires a considerable reduction in power output in typical situations such as close range testing, or simulating flight conditions by continuously reducing the power to the transmitter antenna. Common practice is to reduce the drive to the last power stage, hence, degrading the performance. Bandwidth and modulation characteristics are appreciably affected.

This conceptual device applies to a variable power divider for the output of a microwave transmitter which can remain at full power, preserving the bandwidth and modulation characteristics, and proportioning any amount of the full power from the normal antenna into a dissipative load. The divider consists of four elements: a mode change section  $TE_{10}$  (rectangular) which changes to  $TE_{11}$  (cylindrical) linear polarization; two quarter-wave rotatable plates which change fixed linear polarization to rotatable linear polarization; and an orthomode transducer distributing power to two output ports. The ratio of distribution is determined by the angle between the two quarter-wave plates.

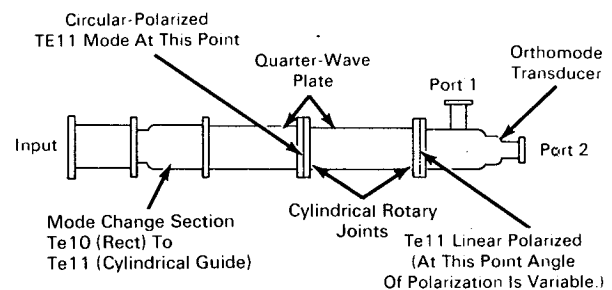


Figure 1

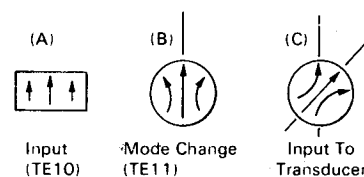


Figure 2

The high-power microwave power divider is shown in Figure 1. The power into the mode change section from the  $TE_{10}$  mode in the rectangular waveguide to the  $TE_{11}$  mode in the cylindrical waveguide is converted to  $TE_{11}$  cir-

cular polarization by the first quarter-wave plate. By rotating the second quarter-wave plate with respect to the first, rotatable linear polarization is obtained at the output of the second quarter-wave plate which is connected to the fixed (relative to input) orthomode transducer. The power into each port is a function of the polarization angle of the incident wave and is controlled by the rotary setting of the second quarter-wave plate.

For example, if  $0^\circ$  is defined as the direction of polarization at the input port (Fig. 2A), the mode is changed to the  $TE_{11}$  circular polarization in the mode change section and the first quarter-wave plate (Fig. 2B). The circular polarization is changed to rotatable linear polarization by means of the second quarter-wave plate and is rotatable through  $360^\circ$ . This input to the orthomode transducer is shown in Figure 2C. The amount of

power distributed to load 1 or load 2 depends upon the angle  $\theta$  setting of the second quarter-wave plate. The power into load 1 (P2) is:

$$P_2 = P_{\text{input}} \cos^2 \theta$$

The power into load 1 (P1) is:

$$P_1 = P_{\text{input}} \sin^2 \theta$$

Therefore, the attenuation from input to Port 2 is:  $A_{\text{(db)}} = 10 \log \cos^2 \theta$  or  $A_{\text{(db)}} = 20 \log \cos \theta$ . Attenuation is a function only of the rotation angle and could be remotely read and controlled.

Source: R. B. Kolbly of  
Caltech/JPL  
under contract to  
NASA Pasadena Office  
(NPO-11031)

*Circle 13 on Reader's Service Card.*

### IMPROVED VHF DIRECTION FINDING SYSTEM

A direction finding device, operating at very high frequencies, has been developed, which should be valuable as a navigation aid. Existing methods require loop antenna, mechanical rotation, and large structures.

A group of four elements, each consisting of two perpendicular dipoles, are arranged in a square. Four of the dipoles are vertical and four are horizontal. Direction information is extracted in the form of a direction cosine analog. Conventional phase measuring equipment can be used to

determine the direction of the received (incoming) signal.

To avoid multipath signals (scattering) from ground reflections, the array should be shielded by a metallic ground plane.

Source: E. R. Graf and Dr. H. Neff of  
Auburn University  
under contract to  
Marshall Space Flight Center  
(MFS-20439)

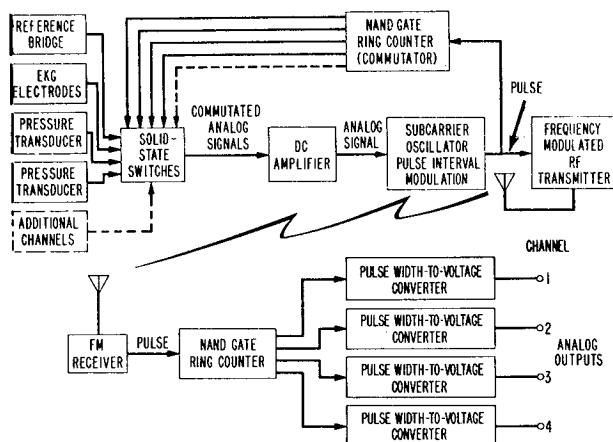
*Circle 14 on Reader's Service Card.*

## Section 2. Telemetry Systems Applications

### MULTICHANNEL IMPLANTABLE TELEMETRY SYSTEM

A multichannel telemetry system has been developed which is suitable for chronic implantation in animals to monitor a variety of physiological parameters. The number of channels can be increased or decreased easily depending upon the requirements of the experimenter.

A hermetically sealed unit using a time-sharing multiplex scheme to commutate between various sensor inputs comprises the basic system. Experiments requiring multiple pressure sensors, EKG, and temperature have been accommodated. Units having 5 and 8 channels have been built and



tested. The essential features of small size and low power required for implantable physiological telemetry have been achieved without sacrificing accuracy and reliability.

The telemetry system is shown as a block diagram. The upper section shows the implanted transmitter part of the system. The lower part of the figure is the receiving and demodulating equipment that provides an analog signal suitable as an input to a pen recorder.

The ring counter is the key element in the operation of this multichannel transmitter. A nand gate ring counter is used as a commutator to operate a series of solid-state switches. There is one switch for each input channel, operated in a sequential manner by the commutator. The commutated signal is amplified slightly and then applied to a subcarrier oscillator. The subcarrier oscillator is used in the system to allow accurate coding of the signal for RF transmission. The subcarrier oscillator generates a series of pulses with a period between pulses of approximately 0.7 msec. Each pulse generated by the oscillator is used to advance the ring counter and the solid-state switch one position to sample the next analog input. The oscillator pulses are also used to frequency modulate an RF oscillator. The RF signal is then radiated by means of an antenna to the receiving system.

Each sensor is connected to the transmitter by lead wires contained in medical grade tygon tubing. Another tygon-covered lead connects to the battery and a magnetic latching switch, which are usually placed just under the skin of the animal, to facilitate operation of the switch and renewal of battery. With this arrangement, long-term (1-2

year) telemetry experiments are possible.

The following is a summary of the major system performance characteristics:

Number of channels—Systems with five and eight channels have been tested, but the system can be adapted easily to more or less channels.

Sample rate—Approximately 0.7 msec per channel.

Frequency response—dc to 50 Hz.

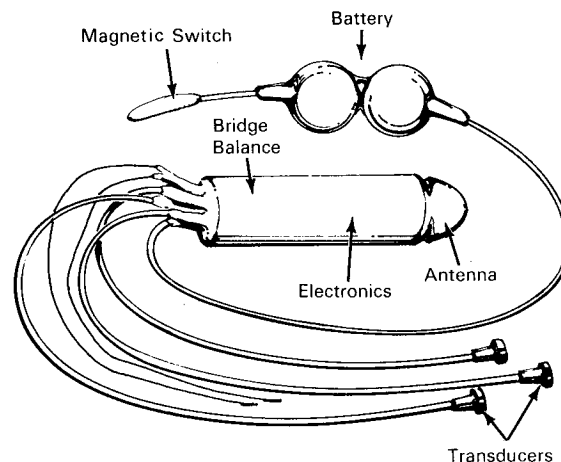
Transient response—5 to 7 msec for five-channel system.

Input impedance—Suitable for 5K strain-gage bridges, or approximately 150K when used with biopotentials such as EKG.

Noise level—Less than 20  $\mu$ V peak to peak, including cross-modulation

Radio-frequency—88 to 108 MHz.

Power supply—2.7 V (2 mercury cells).



Battery drain—Approximately 2.5 ma for the transmitter system. (The total current required by the three pressure cells and reference bridge used in this instance is 1 ma.)

Operating life—200 hours continuous operation using a 500 ma-hr battery.

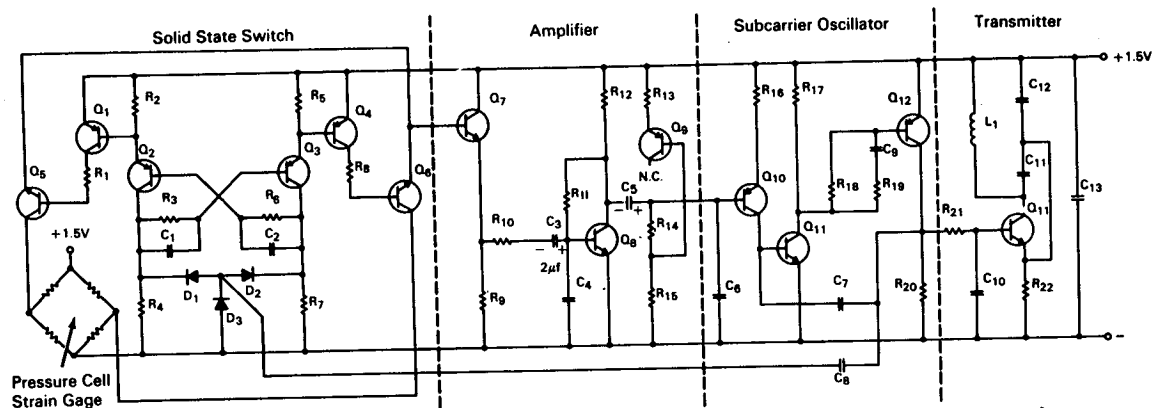
Size—Transmitter (independent of battery and transducers) approximately 1 cm by 2 cm by 8 cm.

Weight—Transmitter, 70 gm. (Two 500-ma-hr mercury cells, pacemaker type, 16 gm). The size and weight could be reduced further by using integrated circuitry.

Source: T. B. Fryer  
Ames Research Center  
(ARC-10083)

Circle 15 on Reader's Service Card.

# MINIATURE TELEMETRY SYSTEM ACCURATELY MEASURES PRESSURE



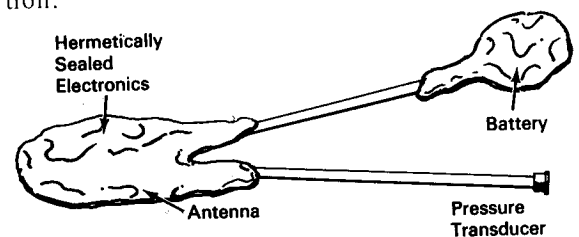
A telemetry system has been designed to accurately measure pressure with a small implantable pressure cell and transmitter. The system operates with low power consumption, and can be used with any of a number of commercially available strain gage pressure transducers. A small, solid-state, strain gage pressure cell, designed for implanted physiological applications, is used with the new circuitry to provide a complete, implantable pressure transducing system.

The electronic circuit employs a pulse code modulation similar to those previously used for temperature and biopotential monitoring. The subcarrier modulation technique allows accurate transmission of the low output level of the pressure cell from an implanted location to a remote radio receiver. The small strain gage signal (approx. 15 mV for 250 mm of Hg) is chopped by means of a solid-state switch ( $Q_1, Q_2, Q_3, Q_4, Q_5, Q_6$ ) and amplified by an ac amplifier  $Q_7$  and  $Q_8$  (gain approximately 5). After amplification, the signal controls the period of an astable multivibrator ( $Q_9, Q_{10}, Q_{11}, Q_{12}$ ) operating at approximately 1 kHz. The pulse derived from the astable multivibrator is applied through  $C_8$  to obtain synchronous operation of the solid-state switch, thereby causing the period of the multivibrator to be controlled alternately by the voltage derived from  $Q_5$  and  $Q_6$ . The difference between successive periods is then proportional to the bridge unbalance signal and hence the pressure. The interval between pulses at bridge balance would be identical, but in order to avoid ambiguity the bridge is initially unbalanced so that one period remains smaller than the other over the entire operating pressure range. A typical modulation

of  $\pm 20\%$  of the mean period is obtained for a pressure change of 250 mm of Hg.

The short pulse developed by the astable multivibrator (approx. 20  $\mu$ sec long) is used to turn on the RF oscillator,  $Q_{13}$ .  $L_1$  is used both as a tank circuit inductor and as a transmitting antenna. Since the information is derived from the time period between RF pulses, amplitude and frequency changes in the RF link do not affect the accuracy. After the pulses are received on a commercial FM receiver (88-108 MHz), a suitable demodulator is used to obtain an analog signal.

The telemetry system is shown with a protective coating of elasticized silicone rubber applied. In this condition, the system is ready for implantation.



This system has been used with pressure transducers, and the circuit is equally applicable to any measurement using a strain gage sensor. The pressure transducer, commercially available, is 6.5 mm in diameter and 1 mm thick. The lead-in wires terminate on the back of the transducer in a package that is 3.5 mm in diameter by 4.5 mm long. The compensated temperature range of the transducer is from 77°F to 113°F. The telemetering electronics are suitable for temperatures to 150°F. The battery lifetime of 500 hours is associated with a transmission distance of 3 to 5 feet. Increased

transmission distance will be accompanied by increased power consumption with a reduced battery life. Battery life would be reduced to about 125 hours for a transmission distance of 100 feet.

Source: T. B. Fryer  
Ames Research Center  
(ARC-00074)

*Circle 16 on Reader's Service Card.*

### TELEMETRY FOR IMPACT ACCELERATION MEASUREMENTS

A telemetry package uses three separate FM/AM transmitters, one for each axis of measurement, to provide a means for impact studies on structures. At the ground station, three inexpensive AM receivers and a tape recorder are used for receiving, demodulating, and recording the acceleration signal.

The output from each axis of the piezoelectric accelerometer is connected to a separate FM/AM telemeter circuit. The input stage of each circuit is a high impedance (300 megohms) voltage follower which drives a voltage-controlled subcarrier oscillator. The center frequency of the subcarrier is set to approximately 54 kHz and is capable of  $\pm 40\%$  deviation for a specified input voltage. The subcarrier output is then used to modulate the RF carrier at 100% amplitude.

At the ground station, three AM receivers (300 kHz bandwidth) demodulate the RF carrier, providing the FM subcarriers at their respective outputs. The three subcarriers are then directly recorded on tape. When the tape recorder is played back using FM-reproduce electronics (center frequency of 54 kHz), the subcarrier is demodulated, providing the analog waveform of the impact acceleration. Performance features include the following: 1) 60 dB signal-to-noise ratio; 2) frequency response 0.5 Hz to 9 kHz; 3) channel cross-talk below the noise level; 4) time correlation (phase shift) less than 1 degree; and 5) acceleration measurements from 0 to 1000g.

Source: Dean R. Harrison  
Ames Research Center  
(ARC-10289)

*Circle 17 on Reader's Service Card.*

### NEW PASSIVE TELEMETRY SYSTEM: A CONCEPT

A conceptual design of a new passive telemetry system enables the monitoring of vital biological functions from living organisms. This system concept has particular merit for applications such as permanent monitor of physiological variables without attached wires, medical research tool for studying animal life, and remote monitoring of stress or strain as in machinery, production processes, and material studies.

This system offers a new approach for extracting information from a body without external connections or power sources. Electromagnetic energy from externally located transmitters is imparted to a specially designed circuit module implanted in the body. The implanted module utilizes the propagated energy to produce an RF carrier for re-radiation which is modulated (either AM or FM) by parametric changes within the sensor.

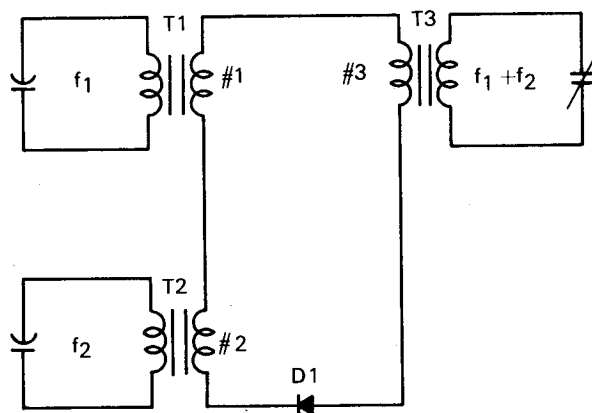


Figure 1 Basic Implant Schematic

The basic operating principle of the system is shown in Figure 1. Miniature transformers T1, T2 and T3 are wound on open ended bobbins of ferrite materials. T1 and T2 are pretuned to sepa-

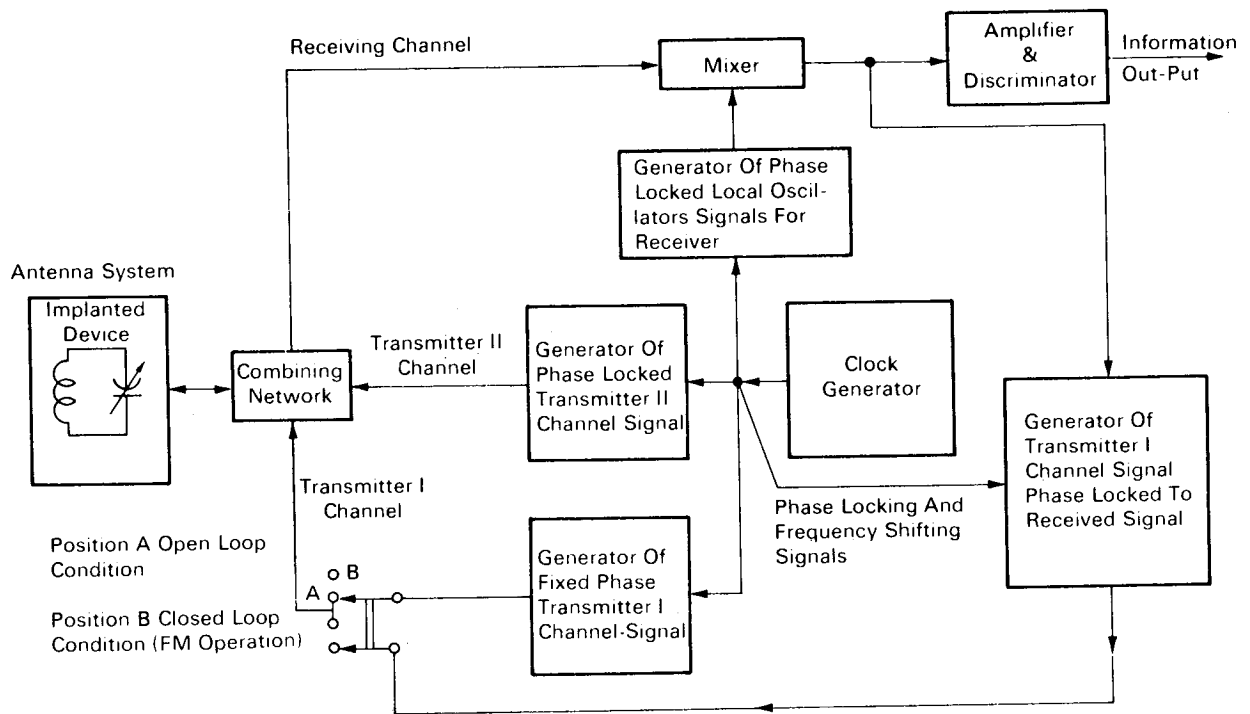


Figure 2 Phase Locked Loop Telemetry System

rate frequencies of external transmitters. The common secondary loop, composed of T1, T2, T3 and D1, is a mixing circuit where sum, difference, and harmonic frequencies  $f_1$  and  $f_2$  are generated. The secondary of T3 is tuned to the sum frequency  $f_1 + f_2$  which is amplitude- and phase-modulated by the parametric reactance of the sensor element. An external receiver-antenna tuned to the sum frequency picks up the reradiated signal which contains the information to be telemetered.

Initial development efforts utilized an amplitude modulated system, but the highly distance-dependent characteristics requiring complex automatic gain controls resulted in an investigation of a frequency modulation system. The FM system has several inherent advantages. The information frequency is nonharmonically related to the powering frequencies by using a phase locked loop technique. There is a virtual elimination of single frequency "cross talk" between power transmitter and information receiver in a passive telemetry system utilizing a completely passive circuit implant. Accurate calibration is possible because the system is independent of amplitude variations and noise such as that normally encountered in AM systems. Also, an improved signal-to-noise

ratio can be obtained using frequency modulation.

The logic for the various modes of operation of the passive telemetry system is illustrated in Figure 2. In the AM version, the information is contained in amplitude modulations of the reradiated sum frequency where  $f_1$  and  $f_2$  remain fixed, and signal fluctuations result from the drifting off-resonance of the tuned circuit as the sensor parameter changes.

In the FM concept, only one of the two transmitter frequencies ( $f_1$  and  $f_2$ ) is fixed. The other is caused to track the instantaneous resonant frequency of the sensor circuit so that the sum frequency is always equal to this resonant frequency. This tracking is accomplished by means of a phase locked loop which is closed through the implant. Changes in phase in the reradiated sum frequency of the implant module are fed back to the frequency control circuits which cause one of the transmitter power frequencies to maintain the phase of the received signal constant.

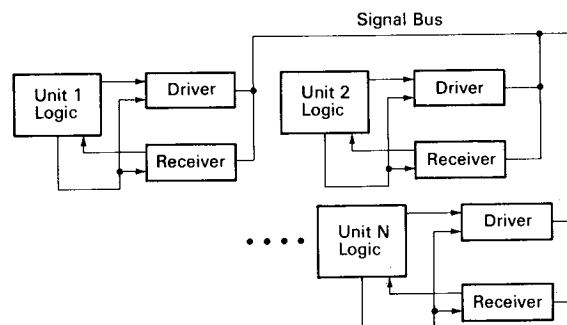
Source: John Visscher of  
Fairchild Hiller Corp.  
under contract to  
NASA Headquarters  
(HQN-10214)

Circle 18 on Reader's Service Card.

### TWO-WAY DIGITAL DRIVER/RECEIVER USES ONE SET OF LINES

A two-way (bilateral) digital driver/receiver system using MOS circuits has been designed for a multiprocessing computer having several subsystems at relatively close locations. Parallel data transfer between several locations has required considerable duplication of equipment and multiple communication lines. The new system requires only a single set of communication lines between subsystems, achieving lower cost with increased reliability.

The basic configuration of the system is illustrated in the block diagram. Each logic unit is associated with a driver and receiver for each word bit. The logic unit sends request signals on individual lines to other logic units, which then control the appropriate drivers and receivers. The receivers incorporate MOS devices, which are of suf-



ficiently high impedance to permit the use of one signal bus.

Source: G. J. Burnett and A. F. Pfeifer of  
North American Rockwell Corp.  
under contract to  
Electronics Research Center  
(ERC-10055)

Circle 19 on Reader's Service Card.

## Section 3. Test and Calibration Procedures

### NUMERICAL DATA FRAME READOUT SYSTEM USED IN TESTING TELEMETRY SYSTEMS

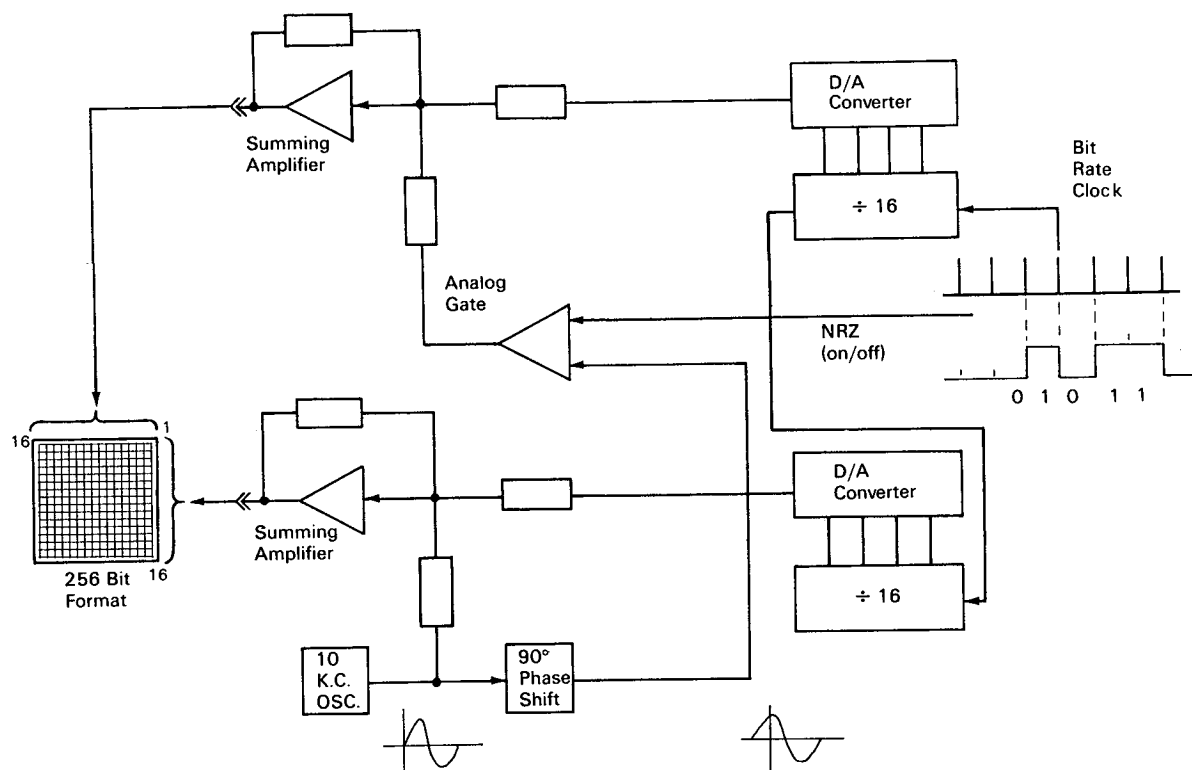
To test digital telemetry systems, previous techniques used a display light and memory device for each data bit presented, or recording printout devices that were inherently slow, requiring data storage prior to readout in high-speed equipment. Oscilloscope raster displays have also been used to present data in non-return-to-zero (NRZ) form rather than numerical form. However, in display light and memory systems, equipment is expensive, data analysis is time consuming, and adaptation to real time is difficult. Oscilloscope raster displays are speed limited by the instrument's response and bandwidth characteristics.

A display system has been developed which offers direct readout at high data rates in numerical format and is adaptable to photographic recording techniques. Bit dropouts at a memory output or location of a failure or malfunction in a particular portion of a system can be shown. Telemetry system operation can also be

checked for errors caused by noise or weak signals in the transmission link; thus determining bit error rates.

The system displays a 256-bit rectangular data format with 16 rows and 16 columns assigned to each frame. The system lends itself to expansion or contraction to suit any desired format. The digital-to-analog (D/A) converters are composed of binary weighted resistors referenced by constant current sources that are controlled by 4-bit binary counters. The counters operate in a pure binary sequence (0 to 15) to produce a linear 16-level staircase function at the outputs of the respective D/A converters.

The 10 kc sine wave oscillator is a phase shift type, wherein the peak-to-peak amplitude is less than half the least quantized interval of the D/A converters. The 90° phase shift network consists of a simple RC network matched to the impedances of both the oscillator and the analog gate. The



analog gate is linear with a very low offset voltage that may, in turn, be compensated by a bias. It is used to pass the 90° sine wave component, undistorted, to the operational amplifier summing resistor whenever a voltage level (binary "1") arrives at its control input from the NRZ data. The absence of a voltage level (binary "0"), in turn, inhibits the sine wave and produces a ground level at the gate output. The operational summing amplifiers have frequency response of 0 to 50 kc and open loop gain of 62 dB.

In operation, the system forms an oscilloscope raster display generated by bit-to-bit and line-to-line electron beam deflection from staircase sweep signals, where each beam location is coherent with an incoming data bit. Coherence is readily established by clocking the binary counters with the bit rate clock. At each beam location, either a "1" or "0" is formed by generation of Lissajous figures, where the particular pattern is determined by the state of a data bit at the NRZ input. In the case of a "1" (voltage level in NRZ

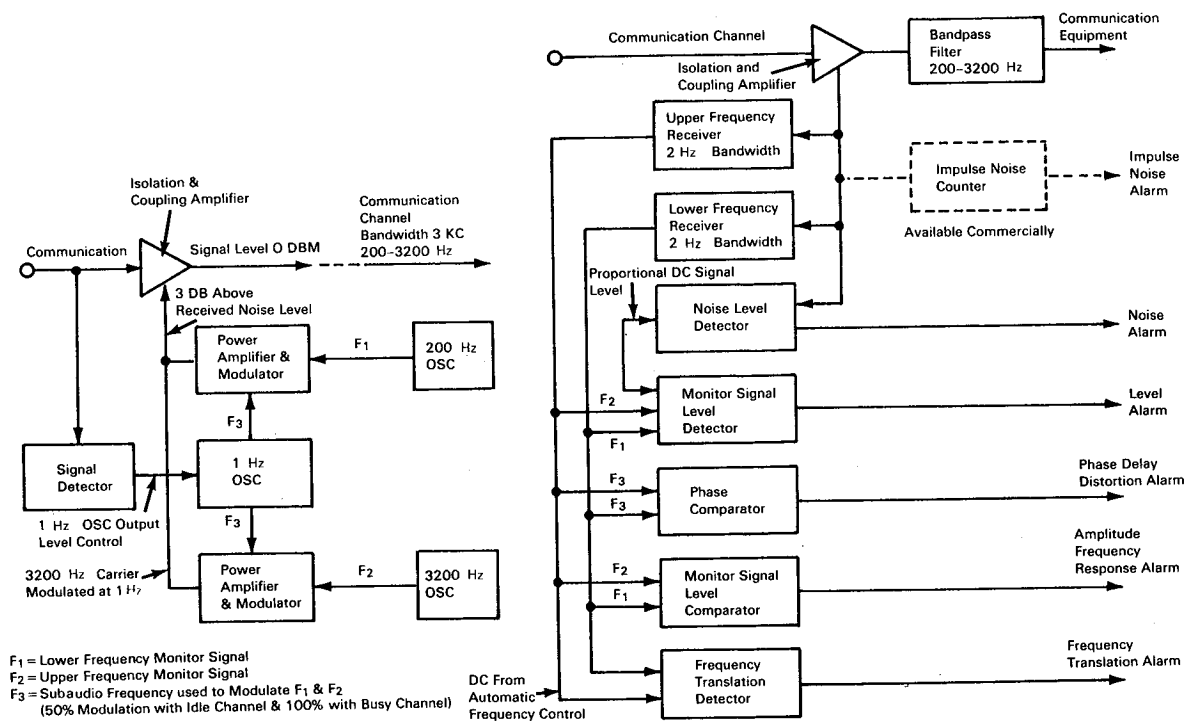
pattern), the vertical input receives a 10 kc sine wave component, while the 90° sine wave component is blanked at the horizontal input. If the data bit interval is 1 millisecond, the electron beam is deflected in a vertical direction over 10 cycles of the sine wave, thus generating a numerical "1" equal in height to the peak-to-peak amplitude of the sine wave. In the presence of a "0" data bit, both vertical and horizontal inputs receive sine wave components, and the 90° displacement in phase angle will cause a numerical "0" to appear. Ten cycles of beam deflection are again encountered for each bit presented, providing ample retrace for use with low persistence or low response time oscilloscopes. Synchronization of readout sequence with incoming data is accomplished by clearing the binary counters at the beginning of the readout sequence.

Source: J. R. Cressey and C. E. Cote  
Goddard Space Flight Center  
(GSC-90551)

*No further documentation is available.*



## MONITOR ASSURES AVAILABILITY AND QUALITY OF COMMUNICATION CHANNELS



Monitor-Signal Transmitter

A monitoring system has been devised that continuously monitors a communication channel for proper circuit parameters and energizes an alarm if these parameters do not fall within allowable limits. The system assures the availability and quality of a communication channel, whether in use or idle. The monitor can be used in voice and high-speed data channels to assure circuit quality and channel availability. It is especially useful in high priority voice channels which do not carry traffic most of the time, but which must be operational and available immediately. In data circuits, it could signal substandard channel conditions that would ordinarily result in lost time and data. Although quality monitoring devices are commercially available and in general use for telegraph and low speed digital circuits, they cannot monitor channels carrying voice or other signals that contain many random frequencies. Also, they cannot monitor all the critical parameters of voice and high speed data circuits.

This system comprises a monitor-signal transmitter at the transmitting end of the channel and a monitor-signal receiver at the receiving end; the

Monitor-Signal Receiver

monitor-signal transmitter generates two amplitude-modulated signals that are within the communications channel frequency band, one at the low frequency end and the other at the high frequency end. The monitor-signal receiver detects the transmitted monitor signal and measures its power level, phase delay, frequency, amplitude response, and degree of modulation. An alarm sounds if any of these measurements do not fall within normal limits.

Transmitter oscillators generate the upper and lower frequencies,  $F_1$  and  $F_2$ , which are used to monitor channel quality. The 200- and 3200-Hz oscillators are typical frequencies only.  $F_1$  and  $F_2$  are amplitude-modulated by  $F_3$ , the output of the subaudio frequency oscillator. A communication signal detector controls the modulating output of this oscillator. During transmissions, the detector increases the output ( $F_3$ ) of the oscillator. This increased output is detected at the receiver, thereby establishing that the communication channel is in use.

The power amplifiers and modulators isolate the oscillators from outside influence and permit

amplitude modulation without frequency modulation. The isolation and coupling amplifier isolates the amplitude modulated monitor signals from the communications equipment and couples the monitor signal to the communications channel. It also provides for manual adjustment of the transmitted monitor-signal level.

At the monitor-signal receiver, the two monitor signals are separated and demodulated by the upper frequency and lower frequency receivers. The demodulated outputs of each receiver ( $F_1$  and  $F_3$ ;  $F_2$  and  $F_3$ ) are fed to the monitor-signal detectors and comparators.

The monitor-signal level detector adds the average power level of the upper and lower monitor frequencies ( $F_1$  and  $F_2$ ) to indicate communications channel signal level and also channel failure (zero-level condition). It also detects when the channel is in use by measuring the power level of the subaudio frequency modulation (50%, idle; 100%, in use). When this increase in modulation is detected, the level detector feeds a dc signal to the noise level detector, indicating the channel is in use.

The noise detector actuates its alarm at levels slightly greater than normal idle circuit noise. When the communication channel is in use, the dc signal from the monitor-signal level detector reduces the gain of the noise detector to prevent the communication signal from actuating the alarm.

The phase comparator compares the phase angle between the subaudio frequency outputs ( $F_3$ ) of

the upper and lower frequency receivers. These outputs are the same frequency, but one has been transmitted by the communication channel as a frequency below the signal band and the other as a frequency above it. Since these upper and lower frequencies started with their modulation in phase, from the same subaudio frequency oscillator, any phase difference at the receiver is a measure of the phase-delay distortion of the commercial channel.

The monitor-signal level comparator compares the received power level of the upper- and lower-frequency monitor signals ( $F_1$  and  $F_2$ ) and thus measures frequency distortion.

The frequency translation detector operates from the AFC error signal generated in the upper- and lower-frequency receivers. An alarm is sounded when this error signal exceeds a predetermined amount.

The bandpass filter removes the monitor-signal frequencies from the communication channel to prevent their interfering with channel use. This filter will not be necessary if the level of the monitor signal can be low enough to be comparable to the normal channel noise.

Source: G. P. Smith of  
RCA Service Company  
under contract to  
Kennedy Space Center  
(KSC-66-38)

*Circle 20 on Reader's Service Card.*

## AUTOMATIC CALIBRATION APPARATUS FOR TELEMETRY SYSTEMS

An apparatus has been designed for automatically calibrating and testing telemetry systems. The apparatus can generally be used to calibrate analog-to-digital converters, in which analog test voltage established at a channel input varies to seek the level of maximum probability of indecision, by servo action.

In the past, calibration of a telemetry system involved the search and identification of average indecision zones and was done manually using complex equipment. Because the indecision zones have quite narrow bounds, test operators had considerable difficulty in locating these indeci-

sion zones and visually interpreting the telemetry output data. The data was used to manually adjust the analog input voltage to the apparatus for establishing the point of maximum probability of indecision. The confidence level of such tests was not high, and operator fatigue was a factor.

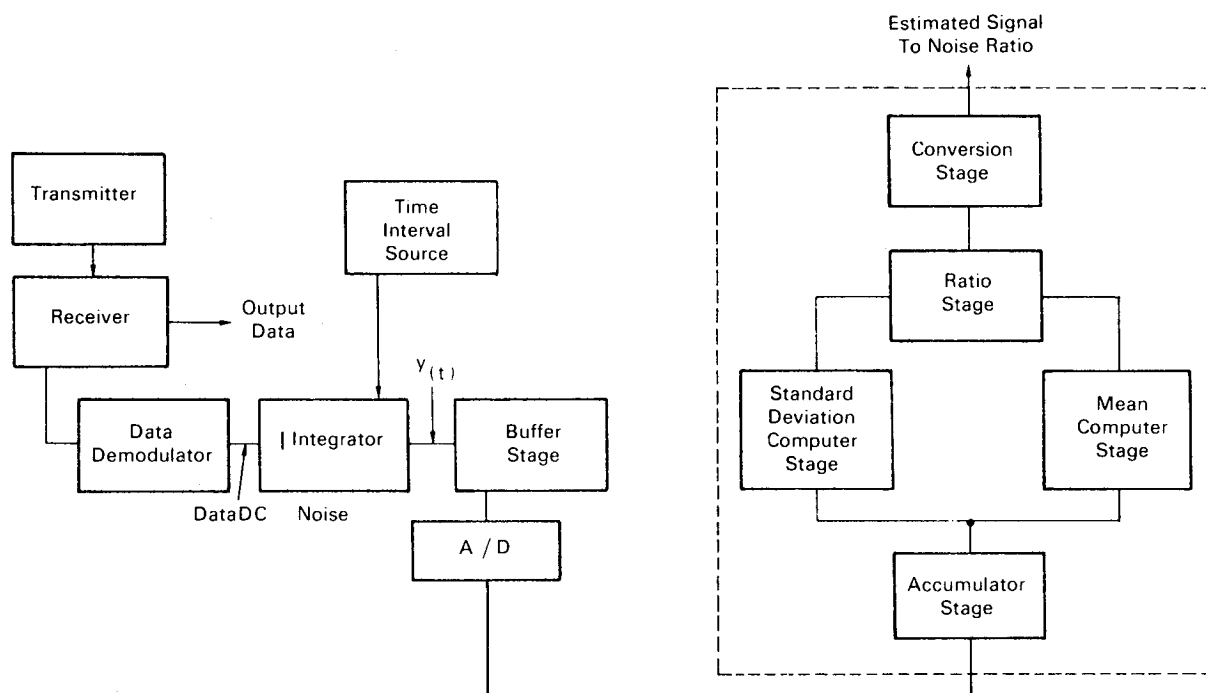
The new apparatus automatically specifies the input function in a closed servo loop. It combines a servo-controlled voltage source and an integrating digital voltmeter with automatic printout. Advantages of the automatic apparatus include: adaptability to various telemetry systems and analog-to-digital converters; accurate setting of

calibration point, even though the telemetry system may have only an arbitrary word length; and greater speed than with other known methods.

Source: W. W. Allen  
NASA Pasadena Office  
(NPO-10560 & 10754)

*Circle 21 on Reader's Service Card.*

### ESTIMATION OF SIGNAL-TO-NOISE RATIOS



A statistical method that estimates the signal-to-noise (S/N) ratio in an observed random voltage such as the output of a telemetry receiver, and enables continual monitoring of it, can be used to determine S/N ratios and modulation indices in long-range communications systems. Signals from a distant transmitting source, overlaid by noise signals, are monitored continuously. During each of a series of successive time periods the signals, plus noise, are integrated to produce an output at the end of each period. These outputs are then accumulated for estimation of the mean and the standard deviation of the outputs, which are related to the S/N ratio.

Estimators for the mean and for the standard deviation are so chosen that the two statistical terms can be derived from a minimum of computations that are all performed automatically by either a special-purpose computer or a properly

programmed general-purpose computer. The mean and standard deviation are derived by accumulation of a minimum number of outputs sufficient for estimation of the S/N ratio with a predetermined degree of accuracy.

By use of the mean and standard deviation for this estimation, and by selection of the particular estimators to fulfill certain requirements, the desired ratio is conveniently derived with a minimum of additional equipment and the least possible delay. This method may be used for detection of the ratios of different signals, emitted simultaneously by the communications system at different frequencies, so that more than one SN ratio may be derived simultaneously.

The power ratio of data signals to carrier signals is a function of the transmitter's modulation index which is generally kept constant. Normally, the power of the carrier signals and noise at the re-

ceiver is predicted closely. Such information, together with the estimated carrier and data ratios, can then be used for verification of the operation of the communications system, and to sense and locate any malfunction.

#### Patent status:

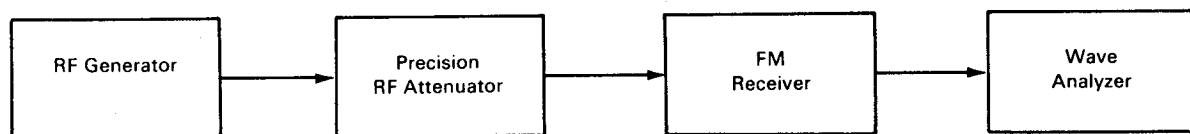
This invention has been patented by NASA (U.S. Patent No. 3,350,643), and royalty-free license rights will be granted for its commercial development. Inquiries about obtaining a license should be addressed to:

Patent Counsel  
Mail Code I  
NASA Pasadena Office  
4800 Oak Grove Drive  
Pasadena, California 91103

Source: C. E. Gilchrist and  
L. A. Couvillon, Jr., of  
Caltech/JPL  
under contract to  
NASA Pasadena Office  
(XNP-05254)

*Circle 22 on Reader's Service Card.*

### GRAPHICAL METHOD TO PREDICT THE DYNAMIC RESPONSE OF FM RECEIVERS



A technique has been devised to determine graphically the RMS threshold point, saturation point, and operating points for an FM receiver utilizing various modulation indices and degrees of submodulation. The receiver operating points for various signals employing different modulation indices and types of submodulation are normally specified by the signal-to-noise (S/N) ratio for efficient receiver operation.

The S/N of an FM receiver is a function of RF input, noise figure, and bandwidth. Measurements for a generalized noise characteristic graph can be accomplished by connecting an RF signal generator to the FM receiver under test. The FM receiver video output is then measured by a wave analyzer (tunable voltmeter) using a suitable bandpass. Selection of a suitable bandpass requires a close examination of the noise at the particular frequency utilized, to prevent erroneous measures of spectral noise density and eliminate external unrelated sources. The signal generator is set to the carrier frequency and not modulated, since it is desired to measure the noise produced in an FM receiver as a function of RF input level. Measurements of the output carrier-to-noise ratio in dB,

for various input values in dBm, are obtained and plotted.

With no RF input applied, the noise amplitude at the video output is maximum. When the RF input power to the receiver is slowly increased, video noise magnitude first remains constant and then starts to decrease. When the receiver noise is greater than the RF input, the receiver cannot distinguish RF input from receiver noise. Further increases in RF input to the receiver cause the magnitude of the video noise to decrease rapidly, until a point is reached when the rate of noise decrease slows down. This point is called the threshold point to designate the level where the RF input magnitude is comparable to the receiver noise magnitude, and receiver noise-suppression begins.

As the RF input is increased beyond the threshold value, change in video noise in dB becomes a linear function of RF input in dBm. This linear relationship continues until saturation is reached. Beyond this point, the output noise shows no further decrease for any additional increase in RF input. This saturation point can be graphically determined as the first increment of RF input for which the output video noise remains constant.

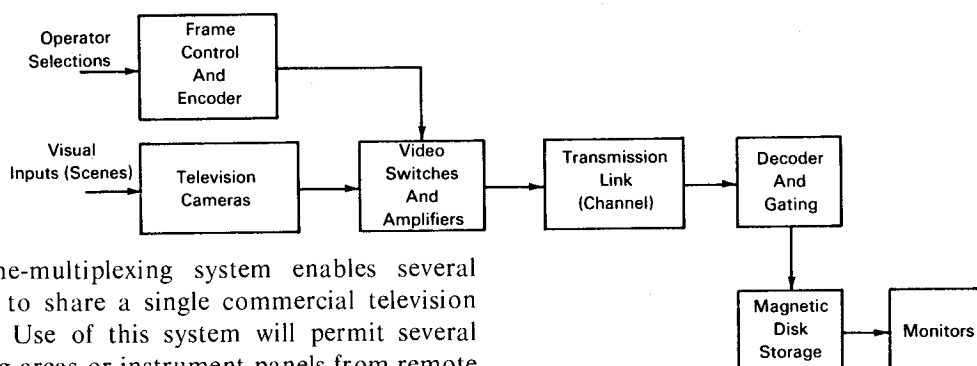
When data concerning a specific modulating system is desired, the receiver RMS video output of the modulating system is measured within the same bandwidth in which noise is measured, and then plotted.

Source: Karl Merz of  
The Boeing Company  
under contract to  
Kennedy Space Center  
(KSC-10111)

*Circle 23 on Reader's Service Card.*

## Section 4. Advanced Systems Technology

### MULTIPLEX TELEVISION TRANSMISSION SYSTEM



A time-multiplexing system enables several cameras to share a single commercial television channel. Use of this system will permit several operating areas or instrument panels from remote locations to be visually monitored. Usually, separate transmission channels would be required for the cameras from different locations.

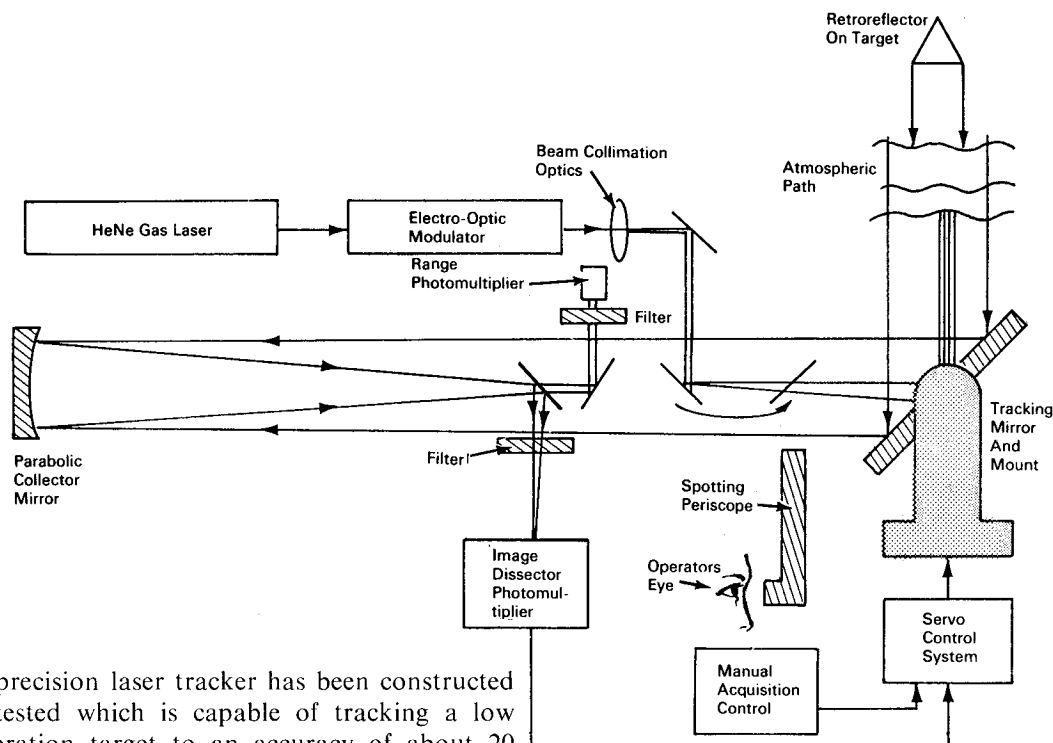
A standard commercial television channel transmits 30 frames (complete scenes) per second. In the multiplex system (simplified block diagram), an operator at the camera end of such a standard transmission link uses control switches to assign the output of each camera to be transmitted during one or more particular frame times in each second, in any chosen sequence. The sequence repeats once each second. The number of frames allocated to each camera is decided on the basis of the expected or observed rates of change of the several scenes to be viewed. Each transmitted frame is identified by digitally encoded signals added to the basic camera signal. Automatic equipment at the monitoring end of the link decodes the camera identification; the successively

transmitted frames are then routed from the various cameras to the corresponding monitors and simultaneously to corresponding magnetic disk recorder/reproducer tracks. The recorded frames from each camera that is not transmitting are reproduced and channeled to the proper monitor at a rate of 30 frames per second. Every monitor thus receives 30 frames per second regardless of how often the content of the frame is changed (transmitted). In this way flicker-free pictures are obtained with resolution and signal-to-noise as good as in a multichannel camera system. Motion rendition would be the only picture quality sacrificed if the picture content changed rapidly.

Source: William R. Reed  
Manned Spacecraft Center  
(MSC-11595)

*Circle 24 on Reader's Service Card.*

## PRECISION CW LASER AUTOMATIC TRACKING SYSTEM INVESTIGATED



A precision laser tracker has been constructed and tested which is capable of tracking a low acceleration target to an accuracy of about 20 microradians RMS. In tracking high acceleration targets, the error is directly proportional to the angular acceleration. For an angular acceleration of  $0.6 \text{ radian/second}^2$ , the measured tracking error was about 0.1 milliradian.

The basic components in this tracker, similar in configuration to a heliostat, are a laser and an image dissector mounted on a stationary frame, and a servo controlled tracking mirror. The daytime sensitivity of this system is approximately  $3 \times 10^{-10} \text{ watts/meter}^2$ ; the ultimate nighttime sensitivity is approximately  $3 \times 10^{-14} \text{ watts/meter}^2$ .

Experimental tests were performed to evaluate both dynamic characteristics of this system and the system sensitivity. Dynamic performance of the system was obtained using a small rocket covered with retroreflective material launched at an acceleration of about 13 g at a point 670 feet from the tracker. The daytime sensitivity of the system was checked using an efficient retroreflector mounted on a light aircraft. This aircraft was tracked out to a maximum range of 15 km which checked the daytime sensitivity of the system measured by other means.

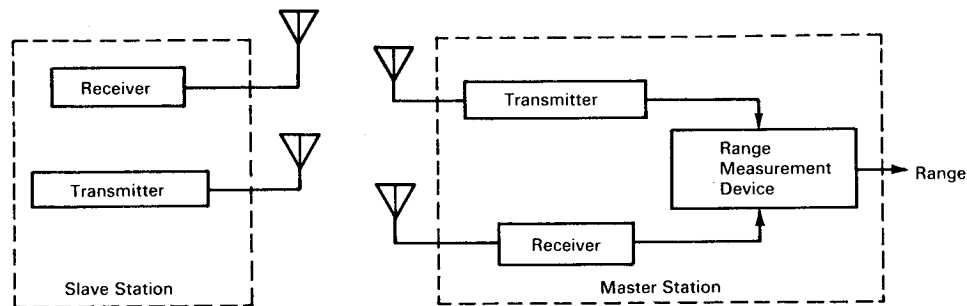
The tracking accuracy against low acceleration targets is comparable to the accuracy of a star tracker. However, the laser tracker has the added capability of measuring range to the target. The accuracy exceeds that which can be provided by a high performance radar.

The advantage of optical tracking over radar tracking is that it is not affected by undesired reflections from surrounding objects, and the accuracy is somewhat less affected by variations in the index of refraction of the atmosphere. Laser tracking, as contrasted to passive optical tracking, has the advantage of discriminating against other optical sources and also has the capability of simultaneously measuring range. High precision tracking is also a necessary part of long-range optical communications which can be accomplished efficiently only by using very narrow beams.

Source: R. F. Lucy, C. J. Peters, E. J. McGann, and K. T. Lang of Sylvania Electronic Systems under contract to Marshall Space Flight Center (MFS-1606)

Circle 25 on Reader's Service Card.

## COMMUNICATION SYSTEM FEATURES DUAL MODE RANGE ACQUISITION PLUS TIME DELAY MEASUREMENT



A communication system has been designed to overcome two very troublesome problems involved in following and measuring the movements of high velocity airborne or space probing vehicles. Additionally, this system may be useful in police and other civil communications systems, and by designers of avionics and commercial communications equipment.

The first problem involves target acquisition and breaks down to (1) providing a sufficient accuracy which requires a high bit rate, resulting in a high doppler shift, necessitating a small range cell per bit; and (2) adequate unambiguous range indications, requiring a low word rate. This system automatically switches between a coarse range measurement or slow code acquisition mode and a tracking mode using combined low word rate signal and a high bit rate signal.

The range acquisition system uses a pseudonoise (PN) code to determine range. In range acquisition, the master station receiver first centers on a coarse quanta from the slave station transponder while simultaneously seeking to center on a fine quanta. Following coarse range acquisition, a dual mode is initiated using half-added coarse and fine quanta signals. The receiver then tracks range using the dual signals with a frequency-controlled oscillator to adjust fine range with detected coarse range. The coarse quanta is chosen so that doppler shift in the system is avoided. When synchronized, PN code generators are used to define the quanta in terms of elapsed time with selected units of the high speed signals being half-added with coarse quanta bits.

The second problem involves a time measurement system that reduces uncontrolled phase variations in the demodulated signal, usually attributable to temperature and other environmental fluctuations. The master station transmitter emits signals modulated by a PN code, and the slave station transponder returns it to the master station receiver. A frequency-controlled oscillator in this receiver is automatically adjusted to determine the time lag or delay, introduced into the modulation components, caused by the propagation time between the two stations, thereby indicating range or distance between the two stations. Typically, the master station transmitter supplies a reference signal to a range measurement device. The master station receiver in turn sends its frequency-controlled oscillator signal as adjusted by the slave station transponder output signal to the same range measurement device. Here, the two signals are compared—the time difference between the reference signal and the frequency-controlled oscillator signal representing the time delay. In addition to propagation time, the total time delay includes delays introduced by the electronics, which, when known, are compensated for.

### Patent status:

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457 (f)], to Motorola, Inc., Scottsville, Arizona.

Source: (MFS-14323)

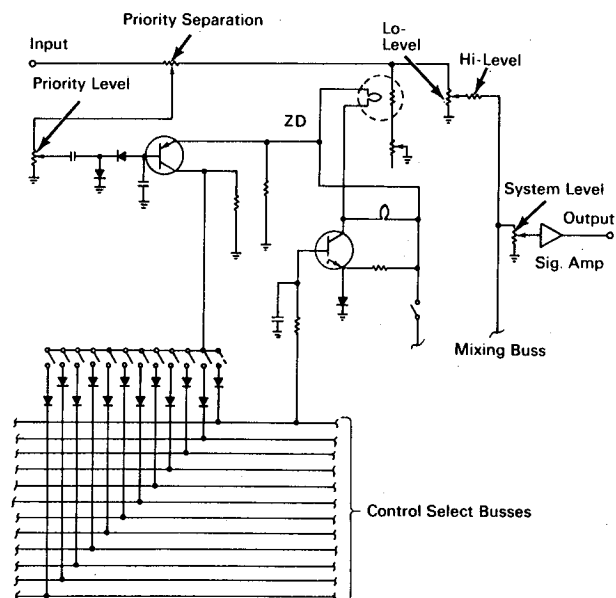
### IMPROVED COMMUNICATION SYSTEM FOR LARGE OPERATIONS CENTER

Sound originating at any given signal source and picked up by multiple microphones provides an effect similar to multiple sources picked up by a single microphone. This effect results in poor articulation (speech clarity) at the output (speaker) because of the varying phase shift at different frequencies and distances.

This problem is largely overcome by introduction into the system of an automatic microphone priority control. Priority is established by an increase of sound level in any single microphone, which causes a simultaneous gain reduction in the amplifiers connected to the remaining microphones. This action suppresses echo and reverberation as a result of the recovery delay incorporated in the circuitry.

The figure illustrates one application of the technique. Priority control distributors (control select) provide negative bias voltage to the input stage of each priority control amplifier. When this voltage is increased, the gain of the input stage of the affected priority control amplifier is reduced. There are 12 priority control distributors in the system. Each distributor input is connected to the dc control output voltage of one of the priority control amplifiers. This output is routed through an isolation diode to 8 or 9 of the 12 priority control amplifier input stages.

The purpose of the signal distribution network is to mix and distribute the signal picked up by the microphones through the amplifiers and speakers at levels relative to the distance from each microphone to each of the speakers. Input to the signal distribution network is made from the output of the 12 priority control amplifiers, while output of the network is connected to the inputs of 16 speaker power amplifiers. The gain between



any given microphone and each speaker is controlled by the signal distribution network and preset at slightly less than the acoustic attenuation between them.

Hum-bucking coils are installed in all microphones to reduce magnetic field interference caused by current-carrying media in the environment. The increased audio communication capability inherent in this system should give added effectiveness to centralized management functions in complex operations.

Source: Melvin S. Draper of  
The Boeing Company  
under contract to  
Marshall Space Flight Center  
(MFS-15016)

Circle 26 on Reader's Service Card.

### DESIGN FOR A RAPID AUTOMATIC SYNC ACQUISITION SYSTEM

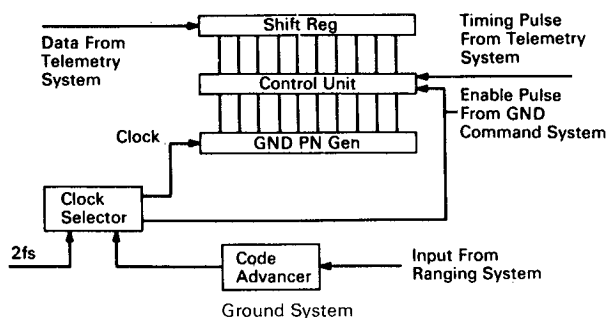
A design has been conceived for a system to provide rapid command sync acquisition between widely separated transmitter-receivers. Use of the system in commercial satellite communications would facilitate rapid sync acquisition between stations and regaining of data lock after interruption or equipment failure. The system is based on

a rapid, automatic range-adjustment approach rather than the time-consuming cycle slipping or stepping techniques of conventional phase-locked loops.

The basic scheme of the proposed system is that of a one-step adjustment of the ground code generator to make it synchronous with the



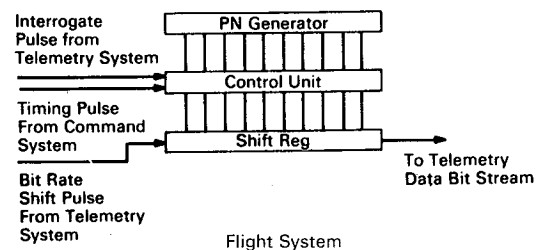
flight code generator. The state or phase of the flight code generator is transmitted to Earth via the telemetry channel, and the status of the flight generator is detected by the ground system. This information is then used to set the ground generator. Assuming there were no delays in the telemetry processing and transmission time, this process would cause synchronization between the two systems. Inasmuch as there are processing and propagation times involved, these parameters must be accounted for. Once the ground code generator is set by the telemetry information, it would be clocked rapidly by the code advancer to account for the delays. (The code advancer derives its data from the ranging system.) Assuming the total time elapsed between sampling of the flight code generator and transmission of the ground code is  $T$  seconds,  $T$  can be multiplied by the total number of symbols which appear in the code sequence to predict the status of the flight command code generator. Only the fractional second-portion of the delay time is used.



At the proper time in the telemetry bit stream, a pulse is initiated in the telemetry system which attempts to activate the control unit. The purpose of the control unit is to transfer the information from the flight command code generator into a shift register which will be clocked out in the telemetry bit stream at the bit rate. To prevent sampling of the flight code generator during a transition time, a timing pulse from the command system is required, in addition to the interrogate pulse from the telemetry system to activate the control unit.

Lock is obtained by the following sequence of events: The information from the telemetry bit stream is recovered and shifted into a register in

the ground system. Upon completion of the input information, the coincidence of a timing pulse from the telemetry system and an enable pulse from the command system cause the ground control unit to set the ground code generator. This action causes the ground code to represent the condition of the flight code generator at the sample time. Since the flight code generator has



changed status during the transmission and processing time, it is necessary to predict where the flight code generator will be at the time of transmission to the spacecraft. This prediction must then be used to advance the ground code generator. The function of the code advancer is to provide high frequency clock pulses to advance the ground generator to coincide with the flight generator. The number of pulses generated is dependent upon the total propagation and telemetry process time. The code advancer will receive the propagation time information directly from the ranging system or through extrapolation. Since the code is repetitious at 1 bps, multiples of 1 second are discarded; only the fractional portions of a second which represent the phase difference between the two codes are utilized.

The proposed system implementation will cause the spacecraft to receive a code which is in phase or very close to being in phase, depending upon the tolerances involved. To overcome some of the problems associated with the tolerances, the codes will be transmitted a fixed number of symbols out of phase. The two codes will then drift with respect to one another for a short period of time until lock is acquired.

Using this system, lock times could be achieved on the order of a few seconds. In contrast with present lock techniques, this number would be fixed.

**Patent status:**

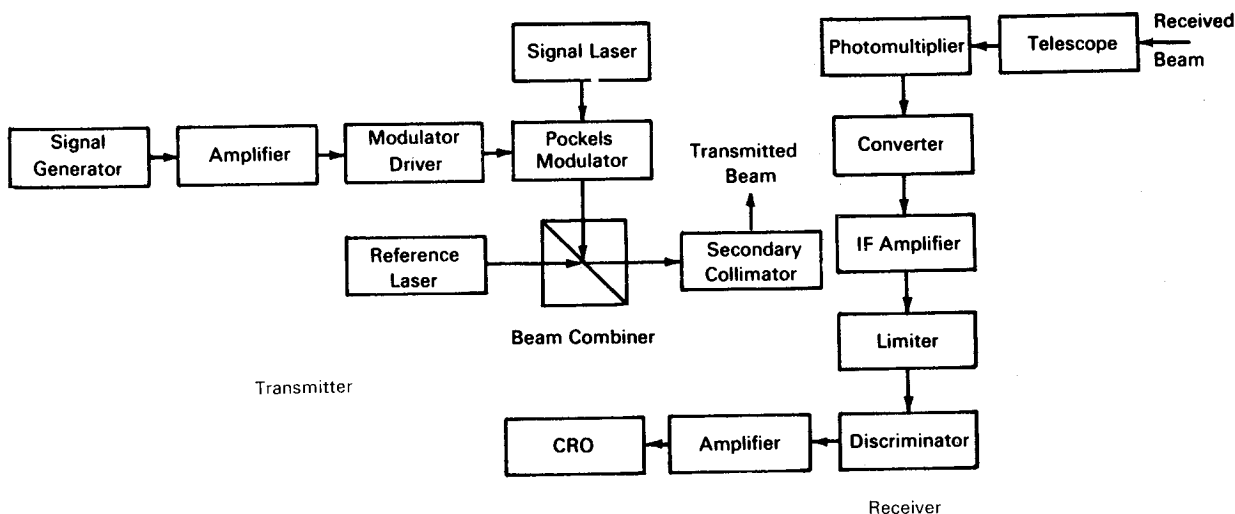
This invention is owned by NASA, and a patent application has been filed. Royalty-free, nonexclusive licenses for its commercial use will be granted by NASA. Inquiries concerning license rights should be made to:

Patent Counsel  
Mail Code I  
NASA Pasadena Office  
4800 Oak Grove Drive  
Pasadena, California 91103

Source: T. O. Anderson and A. J. Gallo  
NASA Pasadena Office  
(NPO-10214)

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### LASER COMMUNICATION SYSTEM IS INSENSITIVE TO ATMOSPHERICALLY INDUCED NOISE



An optical communication system, insensitive to atmospherically induced amplitude noise fluctuations and phase distortions, has been designed. The block diagram shows an implementation of the system for single-frequency subcarrier modulation.

The modulation waveform (intelligence) derived from the signal generator is amplified and applied to a Pockels cell modulator (using a 45° Y-cut ADP crystal) that phase modulates the signal laser beam in synchronism with the modulation waveform. The signal beam laser and reference beam laser are tuned, servo-locked, and stabilized to a difference frequency of 300 MHz. The beams

are collimated, combined, and transmitted through the atmosphere to the receiver. At the receiver, the beam through the telescope is focused on a photomultiplier detector and the difference frequency is generated. The 300 MHz difference signal is amplified, converted to a 60 MHz second IF, amplified, limited, and discriminated to recover the modulation waveform which is amplified and displayed on a cathode ray oscilloscope.

Source: John N. Packard of  
Aircraft Armaments, Inc.  
under contract to  
Goddard Space Flight Center  
(XGS-10396)

*Circle 28 on Reader's Service Card.*

## Section 5. Signal Conditioning and Data Processing

### TELEMETRY DATA CONDITIONING SYSTEM (DACON)

The Data Conditioning routines condition calibrated data with respect to linear interpolation, smoothing and decommutation for input to analysis programs. In addition, the package is capable of time-base correction when extracting calibrated data.

It is assumed that, in addition to the input tape and output tape, if desired, a maximum of two scratch tapes are available to the package.

A maximum of fifty measurement numbers may be processed by the program with no smoothing, or a maximum of ten measurements when smoothing is desired. An additional limitation is that only 480 flagged intervals can be processed

for each measurement number, due to storage limitations. A flagged interval is defined to be one or more flagged data values preceded and followed by a good value.

Language: FORTRAN IV MAP

Machine Requirements: IBM 7094/7040 Direct Couple System

Source: The Boeing Company  
under contract to  
Marshall Space Flight Center  
(MFS-15049)

*Circle 29 on Reader's Service Card.*

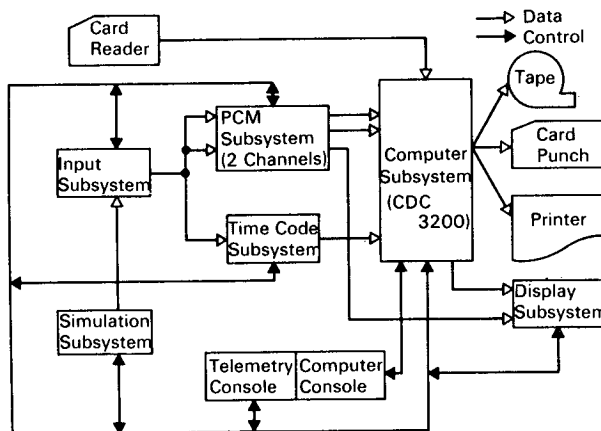
### FULLY AUTOMATIC TELEMETRY DATA PROCESSOR

The "Satellite Telemetry Automatic Reduction System" (STARS II) is a fully automatic computer-controlled telemetry data processor. The system incorporates a CDC 3200 computer as its central element, with facilities for converting and

reduces turnaround time, increases flexibility, and improves operational efficiency. The system encompasses advanced techniques for computer-controlled data processing of high volume telemetry data.

The CDC 3200 general-purpose computer is the basic control element for the complement of signal conditioning, conversion, control, simulation, and computer peripheral equipment. The computer may be used to perform both online and off-line functions. It is provided with a 16,384-word memory, magnetic tapes, card equipment, and a high-speed line printer.

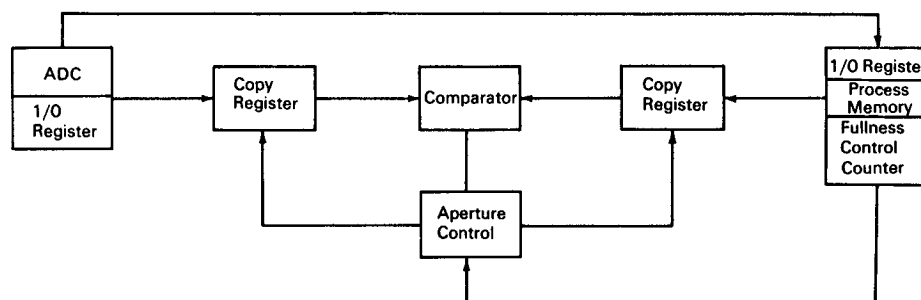
Source: F. A. Keipert and R. C. Lee  
Goddard Space Flight Center  
and F. B. Cox of  
Beckman Instrument Company  
under contract to  
Goddard Space Flight Center  
(GSC-10576)



processing telemetry data and ground station time inputs, plus a full complement of simulation equipment. STARS II maximizes data recovery,

*Circle 30 on Reader's Service Card.*

### A CONCEPTUAL, PARALLEL OPERATING DATA COMPRESSION PROCESSOR



Processors, required to handle increasingly large bit rates in telemetry communications, have become more bulky and complex due to their serial operation at relatively low speeds. A novel data compression processor has been conceived wherein the system is, at the same time, a zero-order processor, a floating aperture, a variable aperture, and a binary integer aperture with a decoded buffer fullness counter directly constituting the aperture.

As an example, the relative magnitudes of two samples can be compared. The first (data point) sample can be assumed to be available in parallel at the analog-to-digital converter (ADC) input-output (I/O) register; the other sample can be available in parallel at the process memory (PM) I/O register. The amount of the aperture is then added to the smaller sample and the two samples are again compared using the same relative magnitude comparator. If the outcome of the second comparison is the same as that of the first, the difference between the two samples is equal to or greater than the amount of the aperture, indicating that the sample should be accepted. Each of the two I/O registers is followed by a copy register so that the original value may be recovered if the outcome of the comparison between the altered and unaltered sample is inconclusive. These copy registers are connected as unidirectional binary

counters with entries at each bit. Connected between the copy registers is a simple qualitative comparator with a single output that is pulsed only when the ADC sample is greater than the PM sample. The output from the comparator at time  $t_1$  controls the adding of the aperture to either copy register. Because the aperture control is a binary integer, its addition to either copy register is simply a one term entry to the specific register at the proper position. The copy registers are connected as binary counters with regular forward carries. After the aperture has been added to either copy register, the output from the comparator at time  $t_2$  will control the transfer of the number in the ADC I/O register to the PM I/O register.

A fixed-aperture processor so described may be modified to provide an exponentially variable aperture that would be a function of the process memory fullness. This would require a shift-right, shift-left shift register containing all zeroes except one "1" at any time. These shift-right, shift-left pulses derive from the process memory fullness level markers. The position of the "1" indicates the aperture size 1, 2, 4, 8, 16, 32, etc.

Source: Tage O. Anderson  
NASA Pasadena Office  
(NPO-10068)

*Circle 31 on Reader's Service Card.*

### ACTIVE SIGNAL CONDITIONER FOR PULSE CODE MODULATION

Spurious sideband components are often generated by abrupt changes in signal frequency associated with binary modulation of an RF signal. These sideband components may cause interference in adjacent channels. Premodulation pulse

train filters commonly use miniature LC filters to eliminate generation of unwanted sidebands in the output signal. However, LC filters typically must be designed for specific bandwidths, and the modulating waveform is not usually symmetrical.

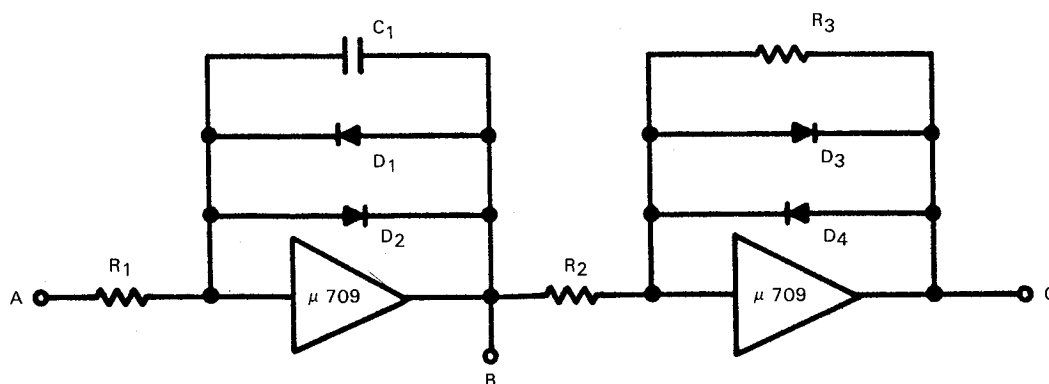


Figure 1. Waveshaping Integrated Circuit Filter

Also, physical characteristics of LC components limit the degree of circuit miniaturization.

Using a diode feedback circuit to shape the modulation pulse waveforms will eliminate spurious upper-frequency components in a signal. A waveshaping integrated circuit filter, shown in Figure 1, uses commercially available components in an active filter configuration. An input

ratio of  $R_2$  to  $R_3$  until a diode ( $D_3$  or  $D_4$ , depending on signal polarity) begins to conduct. The waveshape at C then approximately follows the diode curve until the feedback current (through the diode) completely cancels out the input signal.

The output waveform of the second network is primarily a function of output voltage. The wave-

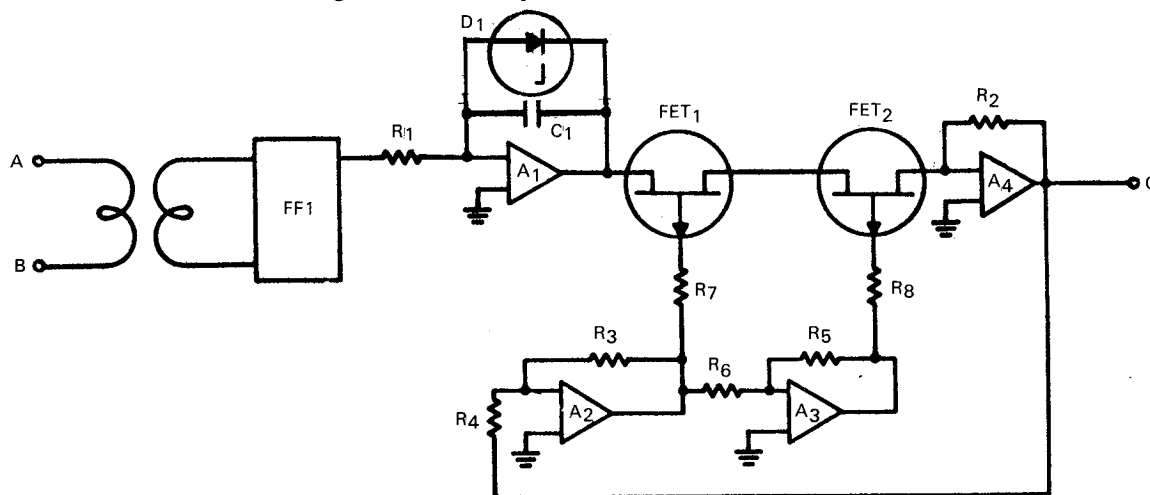


Figure 2. Alternate Waveshaping Integrated Circuit Filter

transition is presented to the circuit at A. The action of the integrated wideband inverting dc amplifier ( $\mu 709$ ) and the feedback network convert the leading and trailing edges of the waveform to a linear ramp that is symmetrically clamped above and below ground at a level determined by  $D_1$  and  $D_2$ . The ramp rate is determined by capacitor  $C_1$  for a given value of  $R_1$  and input swing.

This ramp is fed to a second network. The output of the second network is determined by the

form time function at both B and C is controlled by the value of  $C_1$ . Therefore, the upper limit of the harmonic content of the output waveform at point C can be modified readily by changing only the value of  $C_1$  in the first network. If the harmonic content of the waveform at point C in Figure 1 is excessive for a particular application, any small transients may be removed by adding a third circuit. The output may be set to a desired value by selecting the appropriate ratio of  $R_4$  to  $R_5$ .

Figure 2 illustrates an alternate waveshaping integrated circuit premodulation filter that uses off-the-shelf circuit components. The signal transition rate in this circuit is limited by a servo loop rather than by diodes. Nonlinear operation is provided by making the gain of the control circuit an instantaneous function of its own output.

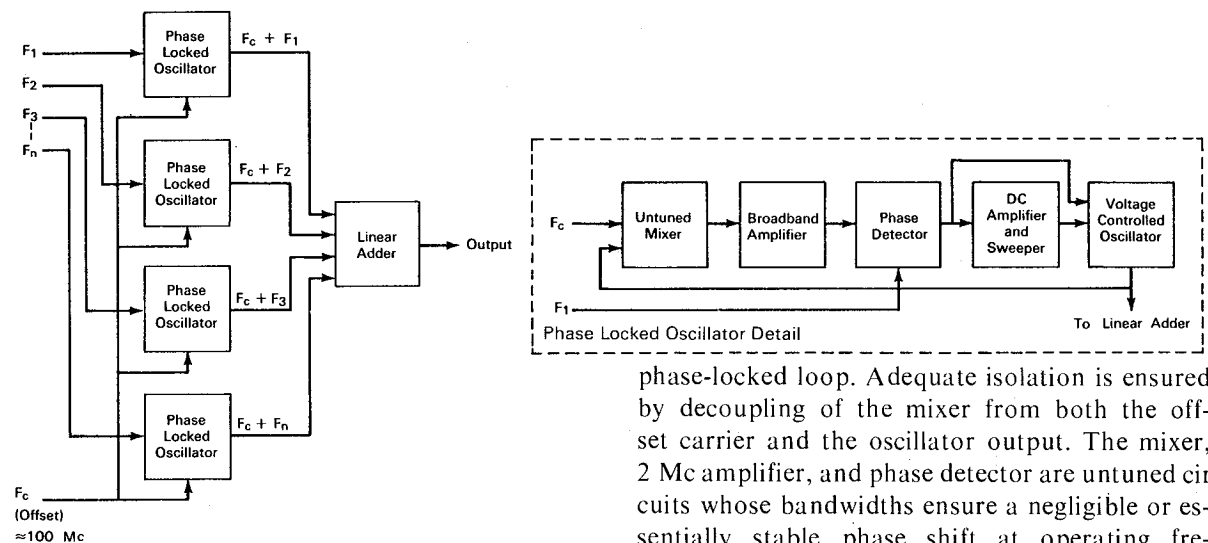
The square-wave input to the circuit at points A and B passes through the flip-flop circuit  $FF_1$ , which provides isolation and normalizes the signal amplitude. Amplifier module  $A_1$  is used as an integrating amplifier. The zener diode  $D_1$  clamps the output voltage of  $A_1$  to produce a ramp waveform. A negative input transition will cause the ramp output of  $A_1$  to go from  $-1$  volt to  $+1$  volt at a constant rate determined by the values of  $R_1$  and  $C_1$ . The two field effect transistors  $FET_1$  and  $FET_2$  are connected in series with the input to amplifier  $A_4$ . The instantaneous gain of  $A_4$  is determined by the drain-to-source resistance of the

$FET_1$  and  $FET_2$  combination and the feedback resistor  $R_2$ . Amplifiers  $A_2$  and  $A_3$  are linear amplifiers. Whenever the initial  $A_2$  output voltage is  $+5$  volts and the initial  $A_3$  output voltage is  $-5$  volts,  $FET_1$  will exhibit a high resistance and  $FET_2$  will have a low resistance. Whenever a voltage transition is applied to the circuit input at points A and B, the output of amplifier  $A_4$  at point C undergoes a transition at a controlled rate because the voltage gain of amplifier  $A_4$  is a nonlinear function of its own output during the transition. The controlled signal output at point C is free of spurious upper-frequency components for any specific bandwidth.

Source: T. P. Harper of  
IBM Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-13357)

*No further documentation is available.*

### SINGLE-SIDEBAND MODULATOR ACCURATELY REPRODUCES PHASE INFORMATION IN 2-MC SIGNALS



A phase-locked oscillator system employing solid-state components has been successfully used in telemetry, aircraft communications and position finding stations, and VHF testing circuitry. The desired output frequency is generated by voltage-controlled oscillators operated in a

phase-locked loop. Adequate isolation is ensured by decoupling of the mixer from both the offset carrier and the oscillator output. The mixer, 2 Mc amplifier, and phase detector are untuned circuits whose bandwidths ensure a negligible or essentially stable phase shift at operating frequency. A sufficiently high amplifier gain is used so that a control voltage for tuning the oscillator over a frequency range equal to that produced by thermal drift requires only 2 to 3 degrees of phase error. Thermal drift of the DC amplifier is minimized by temperature com-

pensation, and the phase detector diode contact potential is rendered negligible by operation at an appropriate level.

This system was developed in the process of generating a delayed signal for a multitone ranging system; it was necessary to single-sideband modulate a series of tones at approximately 2 Mc on a  $100 \pm 0.5$  Mc carrier. A 60 dB rejection of unwanted modulation products and accurate reproduction of phase information contained in the 2 Mc tones were required, together with accurate amplitude control of the relative components. A conventional single-side-

band modulator system did not meet these requirements. Because of the center frequency range, it was not considered practicable to provide matched filters in the conventional circuit to ensure adequate rejection of unwanted frequencies.

Source: Harry F. Strenglein of  
Sperry Microwave Electronics Co.  
under contract to  
Marshall Space Flight Center  
(MFS-664)

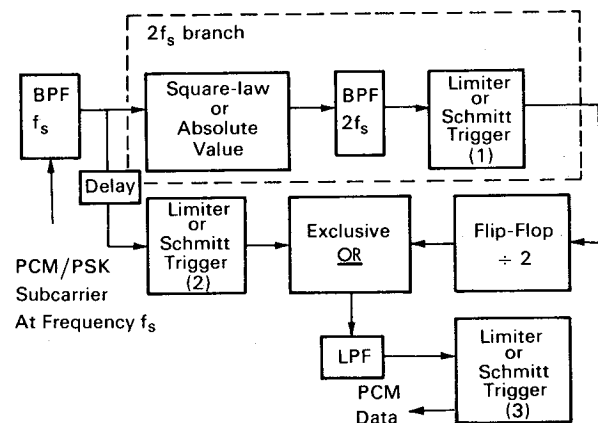
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### SIMPLE DEMODULATOR FOR TELEMETRY PHASE-SHIFT KEYED SUBCARRIERS

The use of phase-shift keyed (PSK) subcarrier techniques in digital pulse-code modulated (PCM) telemetry systems is widespread. Recovery of the PCM data from the receiver output is usually achieved with rather involved circuitry such as a narrow-band tracking loop. Such circuitry is required for operation at low signal-to-noise ratios (S/N), but is too complex or expensive for service in high S/N environments.

A PCM/PSK demodulator, which can be easily constructed from microcircuit elements, has been designed as a simplified circuit having characteristics suitable for the high S/N environment. Applications where low-cost, relatively high-level signal systems are used (i.e., where the ratio of signal energy per bit to noise spectral density is greater than 15 dB) include microwave data links between stations of a network or between data processing facilities. A channel having a S/N of 9 dB, 3 kHz bandwidth, and a bit rate of 500 bps can be demodulated readily by the inexpensive new circuit.

The input to the demodulator is a PCM/PSK subcarrier at frequency  $f_s$  having the form  $\pm \cos \omega_s t$ , where  $\omega_s$  is the frequency ( $2\pi f_s$ ) of the PSK signal and the " $\pm$ " is the PCM data. A bandpass filter (BPF) may be included to separate the subcarriers in a multiple subcarrier system or produce a sinewave output from a square-wave subcarrier input. This filter can be a common active-filter type. In some applications the filter will not be necessary. The sinewave out-



put of the bandpass filter (BPF) with center frequency at  $f_s$  is applied to the square-law or absolute value circuit in the  $2f_s$  branch of the demodulator. The input  $\pm \cos \omega_s t$  is squared by the square-law circuit, producing a double-frequency signal ( $\cos^2 \omega_s t = 1/2 (1 + \cos 2\omega_s t)$ ) of constant phase. Physically, the square-law circuit may be an operational amplifier with the proper diode network. The bandpass filter with center frequency at  $2f_s$  (double the subcarrier frequency) blocks the DC output of the square-law detector and, if necessary, "rings" at the double frequency ( $2f_s$ ) during data transition transients. The  $2f_s$  output of the bandpass filter is applied to the Limiter-Schmitt trigger circuit (1) where it is transformed into a logic level having a single polarity and twice frequency which is divided by two in the flip-

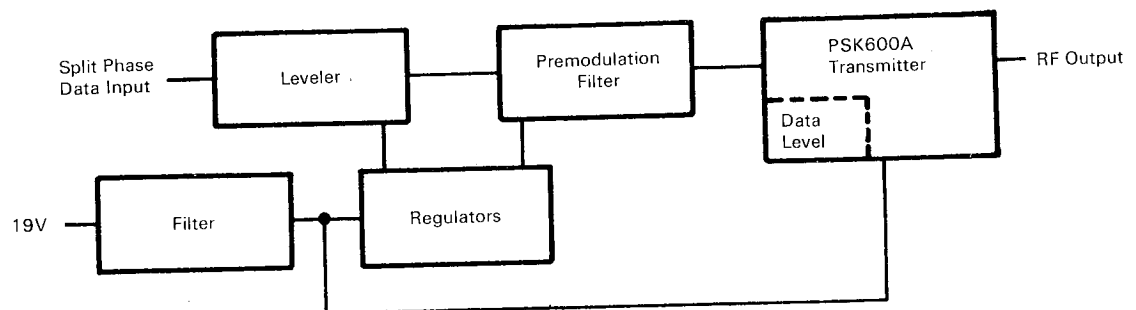
flop. The single polarity  $f_s$  output is applied to an exclusive OR circuit functioning as a synchronous detector. The flip-flop and exclusive OR blocks are standard integrated circuits. The double polarity signal  $\pm f_s$  to be detected is applied to the other input of the exclusive OR circuit and is delayed by a resistance-capacitance network to compensate for delay through the  $2f_s$  branch so that the limited-level signal from the limiter (2) is coincident in time with the signal from the  $2f_s$  branch.

The modulo 2 addition by means of the exclusive OR circuit results in demodulation of the  $f_s$  signal. This signal is applied to a low-pass filter (LPF) to further reduce "glitches" due to time delay unbalance in the  $f_s$  and  $2f_s$  branches.

Source: L.A. Couvillon  
NASA Pasadena Office  
(NPO-11000)

Circle 33 on Reader's Service Card.

### MODULATING FILTER FOR PSK 600A TRANSMITTERS



A linear phase active radio frequency filter has been used to reduce the spectral energy emitted outside a transmitter's assigned RF band. A signal decomposition technique is employed to separate the desired signal from the unwanted residue; the filter may be useful as a band-spread suppressor for microwave data transmitters and very high frequency voice communication systems.

Originally, this filter was developed to assure that the transmitted bandwidth requirements of the Orbiting Solar Observatory (OSO) were fulfilled. The transmitted bandwidth at the 10 dB points, under all conditions of modulation, doppler shift and transmitter oscillator instabilities, were not to exceed the assigned channel bandwidth. To meet this requirement, a premodulation filter was to be used in conjunction with a modified PSK 600A OSO transmitter.

A filter was included to reduce RF from the transmitter on the plus 19 V bus (see fig.). The transmitter was modified to the extent that

its internal data leveling circuit was disconnected and the output of the filter was fed directly to the phase modulator

The input to the leveler circuit was a signal of  $14.4 \text{ bps} \pm 2\%$  with a positive signal voltage of 2.6 V in the playback mode. The output to the leveler circuit was a voltage of zero volts with zero volts on the input or +6 V with a positive signal voltage in. The output impedance in either case was 6.8 K ohms.

The filter is a five-pole, linear phase, active low pass filter with the 3dB point at 36 kHz. The output voltage amplitude was made adjustable by selection of resistor values during the matching procedure to ensure that the premodulation filter could be matched to transmitters with variations in their modulation sensitivity.

Source: Ball Brothers Research Corp.  
under contract to  
Goddard Space Flight Center  
(GSC-11102)

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## OPTIMUM FM PRE-EMPHASIS: A CONCEPT

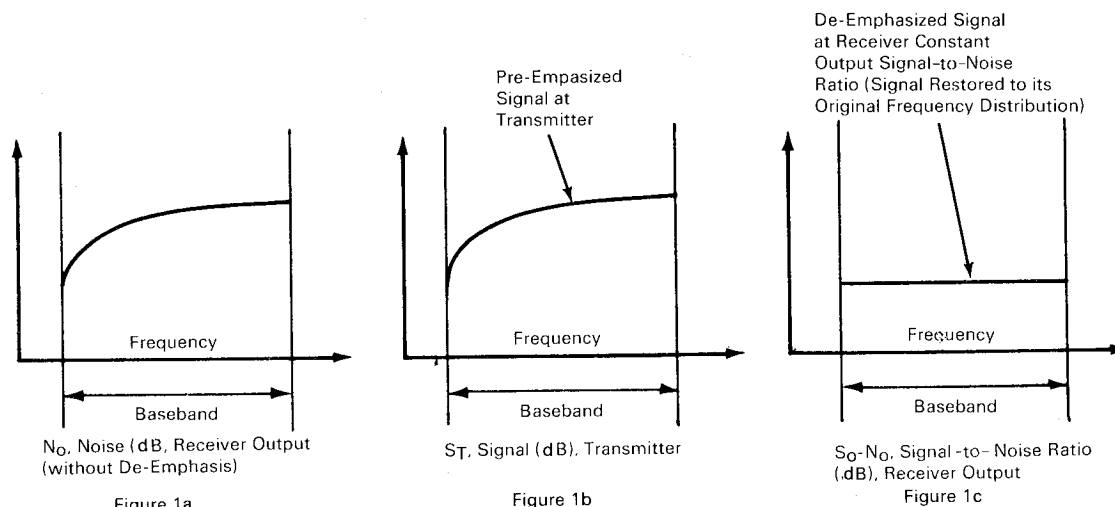


Figure 1a  
Figure 1b  
Figure 1c  
Typical Noise, Pre-Emphasis and De-Emphasis Response Characteristics for an FM Communication System

Frequency modulated communication systems that operate under varying RF input power conditions use a generalized pre-emphasis schedule that provides improved communication reception. In many instances, a receiving system operates with a fixed RF input power. The optimization of FM systems, operating with a fixed RF input power, requires the use of a particular pre-emphasis schedule.

To accomplish this optimization, a conceptual technique was developed whereby the actual pre-emphasis required for a particular frequency modulated system could be precisely determined. This technique has potential application throughout the communications industry, and can be implemented to determine a generalized pre-emphasis schedule for communications systems that operate under varying RF power conditions.

and de-emphasis are required whenever the noise amplitude varies significantly for different frequencies in the baseband (Figure 1a). FM pre-emphasis at the transmitter accentuates certain baseband frequencies with respect to other frequencies in the baseband (Figure 1b). The complementary FM de-emphasis at the receiver de-accentuates those frequencies in the baseband that were originally pre-emphasized by the transmitter, and maintains a constant output signal-to-noise ratio density throughout the baseband (Figure 1c).

A typical pre-emphasis schedule assumes that the noise power amplitude (in dB) in the baseband is a linear function of baseband frequency which is independent of receiver RF input power. These assumptions, although not rigorous, provide acceptable results for generalized

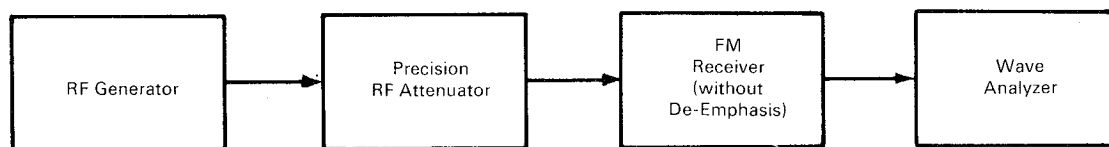


Figure 2. Equipment Test Setup

Typical FM systems are not frequency modulated with a constant modulation index for all baseband frequencies. Instead, they use a signal pre-emphasis circuit at the transmitter and a complementary de-emphasis circuit at the receiver to optimize system operation. Pre-emphasis

communication systems operating under varying receiving system RF input power conditions.

In many instances, a receiving system operates with a fixed RF input power. This is common in closed loop systems and certain "short haul" open loop systems. The optimization of opera-

tion of these specialized systems requires the utilization of a particular pre-emphasis schedule for the specific operating RF input power.

The determination of the pre-emphasis required for optimization of FM system operation requires a precise knowledge of the spectral noise characteristics in the baseband of the receiver (without de-emphasis) as a function of RF input power. The noise,  $N_0$ , in an FM receiver baseband, is a function of RF input power. The signal,  $S_0$ , understood to be the information portion of the wave which the receiver processes in latter stages, produces negligible additional noise. As such, a carrier frequency signal can be used to determine the spectral noise characteristics, in the baseband of the FM receiver, as a function of RF input power.

Figure 2 shows the test setup used to determine the spectral noise characteristics in the receiver baseband (without de-emphasis) as a function of RF input power. A calibrated RF signal generator and precision RF attenuator are connected to a wave analyzer (tunable voltmeter). The wave analyzer measures the noise in a small frequency slot centered at a specified baseband frequency. The RF generator and

FM receiver are set to the operating carrier frequency. The wave analyzer is then tuned to a frequency near the low end of the baseband frequency spectrum. The RF signal generator output power is varied in discrete increments over the dynamic range of the FM receiver. The wave analyzer measures the noise in the selected baseband frequency slot for each discrete increment of RF input power. The results, Output Noise (dB) vs RF Input Power (dBm) for the specific baseband center frequency, are then plotted on a graph.

The wave analyzer is now tuned to a different frequency in the baseband, and data for another curve is obtained and plotted on the same graph as previously described. A family of curves is obtained by tuning the wave analyzer in discrete increments over the entire baseband spectrum.

Source: Karl W. Merz of  
The Boeing Company  
under contract to  
Kennedy Space Center  
(KSC-10151)

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